



BIOLOGY 20

Matter and Energy in Cells

Module 5



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Matter and Energy in Cells



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Module 5
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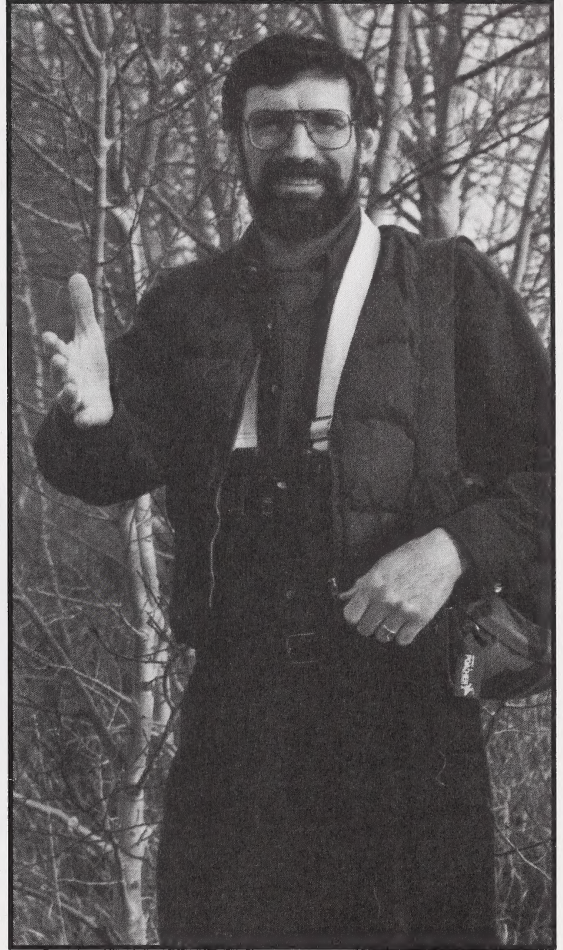
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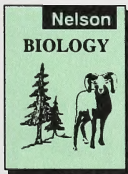
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Welcome to Module 5

We hope you'll enjoy your study of *Matter and Energy in Cells*. Remember, to make your learning a bit easier, several videocassettes and laser videodiscs are referred to throughout the modules. Also your textbook *Nelson Biology* will enhance your studies.

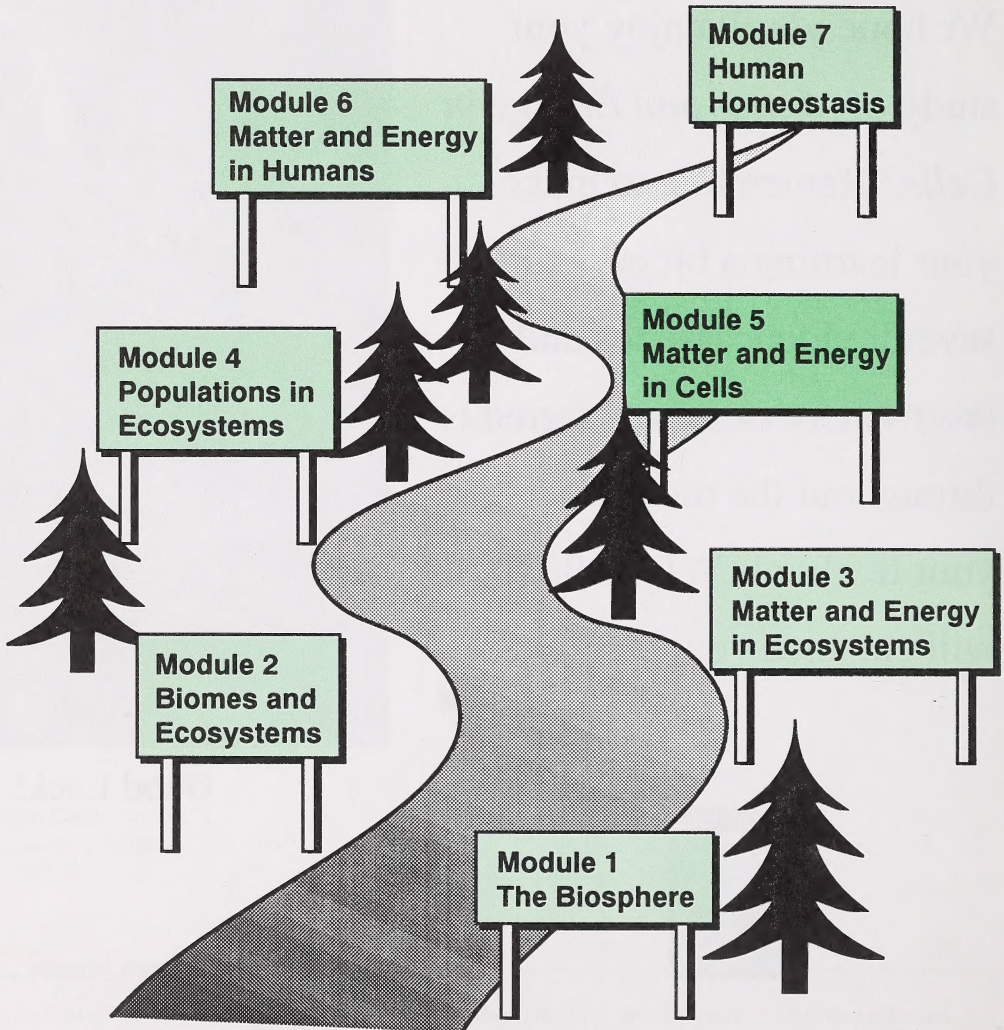


Good Luck!



COURSE OVERVIEW

This course contains seven modules. The module you are working in is highlighted in a darker colour.



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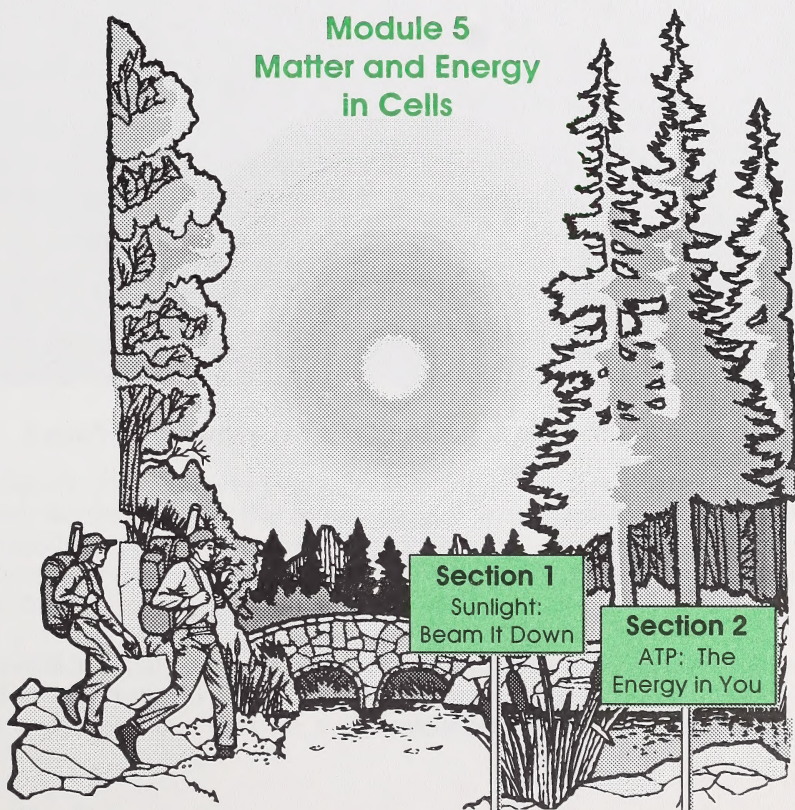
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MODULE OVERVIEW

A mountain lion moves silently through the lower forest toward a group of grazing mule deer. Several of the animals lift their heads and look nervously around and then resume their feeding. Slowly moving closer, the lion keeps her body close to the ground, hidden from view. Suddenly she springs into action. The deer immediately take flight – but it is too late. The charging lion overtakes one of them and pulls it down quickly. In a few moments it is all over. The lion drags the dead deer away and begins feeding on it. A distance away the deer have resumed their grazing, seemingly as if nothing had happened. All the while the warm Alberta sun shines down on the entire scene.

Deer obtain energy for life by eating vegetation while mountain lions must kill and eat other animals to obtain energy. The source of all this energy for the growing grass, grazing deer, and feeding lion is the sunlight that bathes Alberta. In Modules 1 and 3 the entry of energy into the biosphere and its transfer through food chains were studied. Module 5 examines the processes of photosynthesis and cellular respiration as chemical reactions which make life possible.



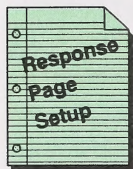
Evaluation

Your mark in this module will be determined by how well you complete the assignments at the end of each section. You must complete all assignments. In this module you are expected to complete three assignments. The mark distribution is as follows:

Section 1 Assignment	50 marks
Section 2 Assignment	<u>50 marks</u>

TOTAL 100 marks

When doing your assignments, work slowly and carefully. If you are having difficulties, go back and review the appropriate section.



Read all parts of your assignment carefully. Plan and do your rough work on your own paper. Revise and edit your responses; then set up your final copy for submission on your own paper. Lined looseleaf is recommended. Make sure your answers are neat and organized, with wide left margins and space for teacher comments after each assignment.

When you see this icon, ideas and details are provided to help you set up and organize your answer in a certain way.

Before submitting your responses, be sure to proofread them carefully to ensure they say what you want, that they are neat and clear, and that they are complete and missing no material.

You will be submitting **only** your **assignment response pages** for evaluation.

It is important to number and clearly identify each page with this information placed at the top.

Biology 20 – Module 5 **Section # Assignment** **Page #** **Name and ID #**

SECTION

1

Sunlight – Beam It Down



WESTFILE INC.

As a student of biology have you noticed that some plants can turn their leaves towards the sun? It is little wonder that ancient people worshipped the sun and believed that all life depended on it. In a way they weren't far wrong. Though it begins 160 million kilometres away, sunlight is the key to life. This is easy to accept, but how easy is it to understand?

In this section you'll explore the energy systems that trap sunlight and convert it to useful energy. You will look at some of the key reactions that occur in living systems and even study some of the ways this knowledge is used in agriculture and forestry.

ACTIVITY

1

The Chlorophyll Trail



WESTFILE INC.

If a young child were to ask you why plants are green, you would probably come up with a very imaginative answer to satisfy the needs of the child. Wouldn't it be great if you knew the scientific answer and were able to give that child a better understanding of why plants were green? You know that the reason plants are green is because of chlorophyll, but what exactly does chlorophyll do? How does it work?



Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Take out the microslide viewer and read the introduction to slide set 119, Green Plants. Look at slide 1 and read the information on plant structures. Look at slide 2 and read the information on the green leaf. Answer the following questions relating to slide 2.

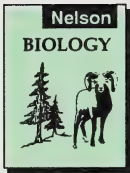
1. What is the chemical that gives leaves their green colour?
2. What can chlorophyll do in the cell?

Slides 2 to 6 review more plant structures. Slide 7 shows the structure of the plant cell that produces food. Read the information on slide 7 and view the slide. Answer the following questions relating to slide 7.

3. What layers are stacked to form a chloroplast?
4. Give the name of the food-making process.

Look at slide 8 and read the information on the leaf with starch. Answer the following questions.

5. Why is the top half of the leaf lighter in colour than the bottom half?
6. Why was the bottom half of the leaf able to produce starch?



If you don't have a microslide viewer and slide set 119, Green Plants, use Figure 7.23 and the information on pages 190 and 191 in your text to answer the preceding questions.

Look at the overall photosynthetic reaction on page 190 in your text.

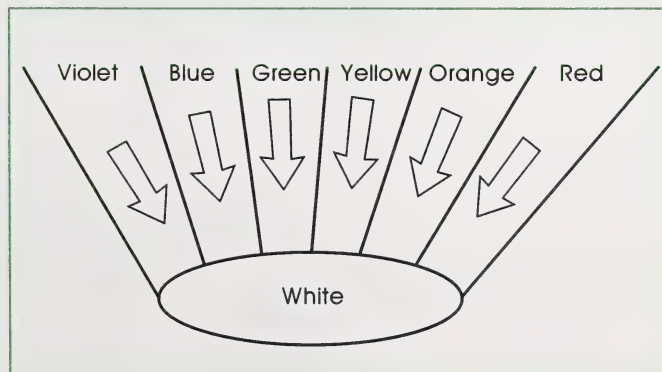
7. Study Figure 7.22 and write out the chemical equation and word equation given for photosynthesis. Circle the source of energy and its final form in each equation.

Read over the five margin definitions on page 190 as well. These will become important to you in the rest of this activity.

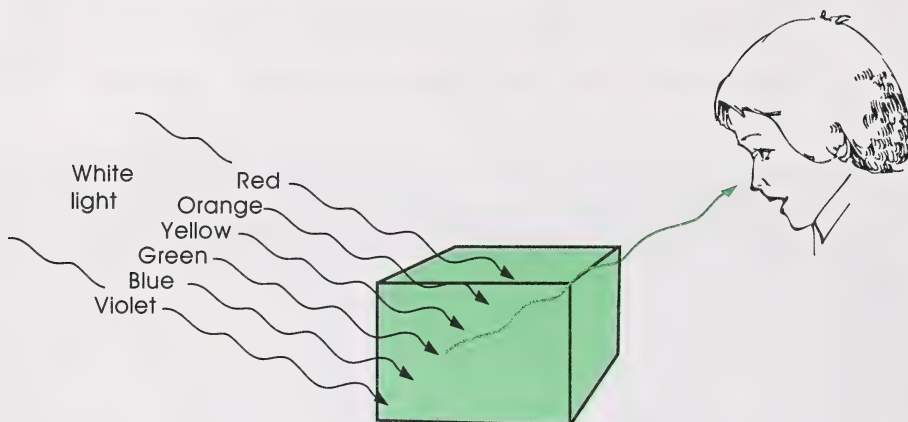
Check your answers by turning to the Appendix, Section 1: Activity 1.

Just as a young child wonders about the colour of plants, scientists in the past also wished to understand the complexities of plant colour.

Here's something to keep in mind. You may recall from previous science knowledge that white light is made up of all the colours of the rainbow.



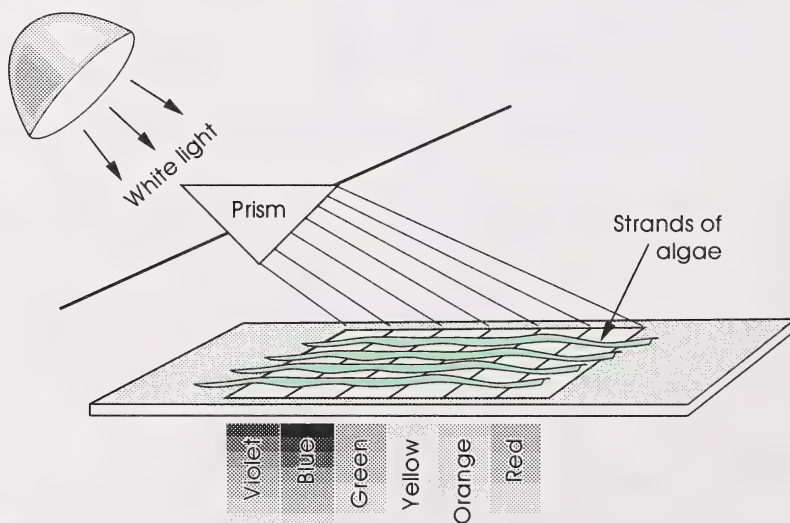
The colour of an object that you see is really a **reflected** colour. All others are absorbed.



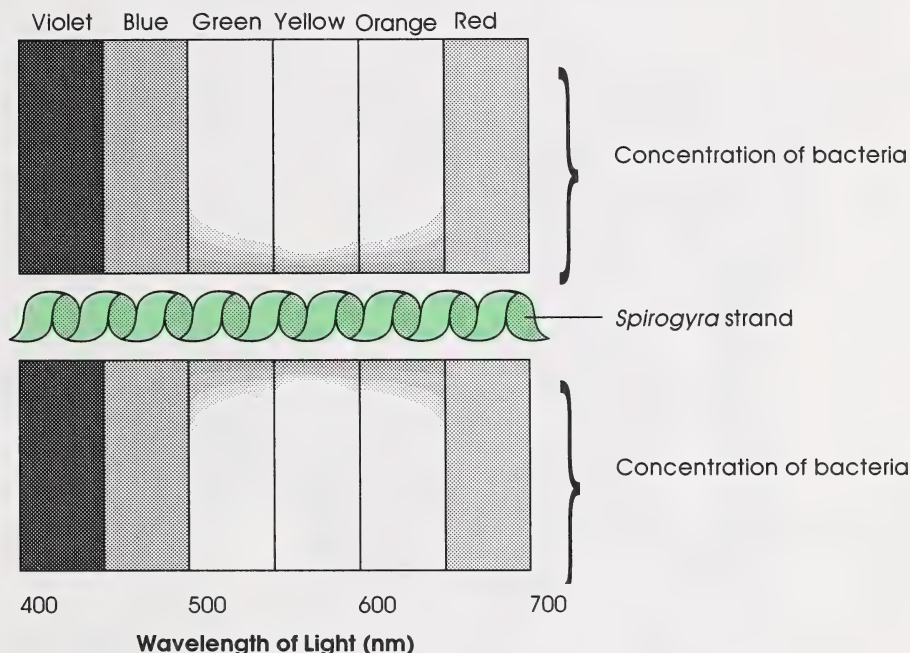
8. What colour would an object appear if it absorbed violet, blue, green, yellow, and red light?

Do you get the idea? Plants are green because they reflect green light from the spectrum. The other colours are absorbed and possibly used by the plant in photosynthesis. Can you think of an experiment to determine which colours plants use?

In 1883 a German biologist, T.W. Engelmann, stretched strands of green algae *Spirogyra* over a microscope slide. Bacteria that grew best in the presence of high amounts of oxygen were also added to the slide. The bacteria were present to indicate where oxygen would be produced. The light that was projected onto the slide was first passed through a prism so that it was broken into the colours of a rainbow. The light was allowed to shine on the slide for a few minutes and the following results were observed.



After a short time this is what he saw through his microscope.



Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

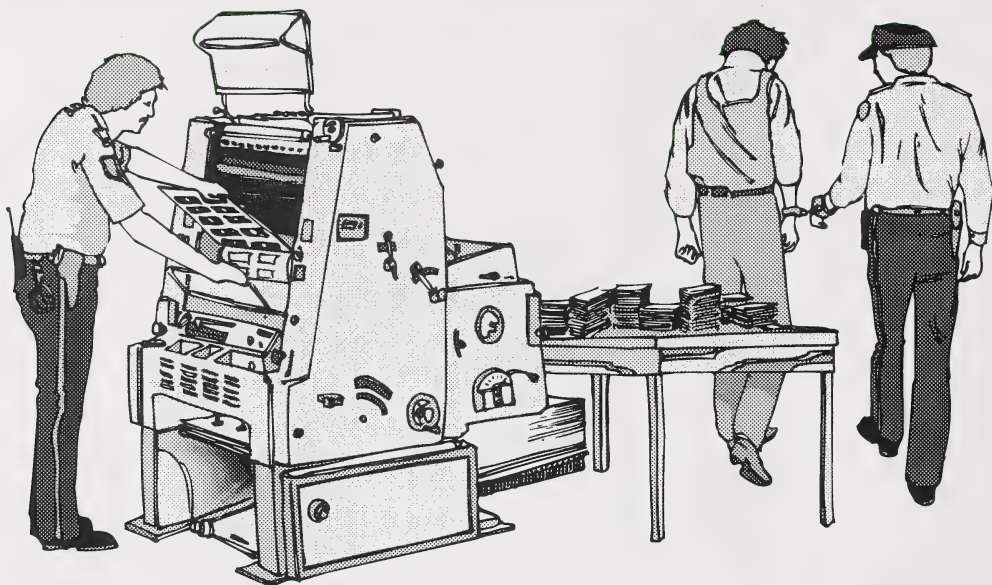
9. What was the purpose of Engelmann's experiment?
10. State the manipulated and responding variables from the experiment.
11. What was the purpose of adding the oxygen-seeking bacteria?
12. Write a conclusion that summarizes what this experiment demonstrated.

Check your answers by turning to the Appendix, Section 1: Activity 1.

This same information can be collected using a modern instrument called a spectrophotometer. You may learn more about this technique in the Enrichment component of this section.

Plants are green because of chlorophyll, and chlorophyll seems to be the key to photosynthesis. This might be a good time to take a closer look at the technology of studying those pigments. Do the following investigation.

Investigation: Separating Pigments Using Chromatography



Objective

Did you every wonder how counterfeiters of paper money are caught even though the colour of the ink or paint they used matches the original? The scientific process of **chromatography** is used to catch these criminals. Chromatography is a method which separates chemicals from each other when they are in a common solution. Perform the following experiment to discover the process of chromatography. The object is to separate a pigment into its colour components.

chromatography
— a method that separates chemicals in solution and collects them on different areas on absorbent paper

Background Information

Paper chromatography is a method used to separate different compounds in a solution. As the solvent (water) moves up the paper, it will carry dissolved compounds of the solution. The compounds move up the paper at different rates due mainly to their solubility in the solvent.

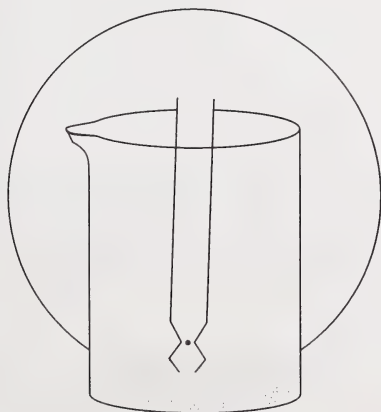
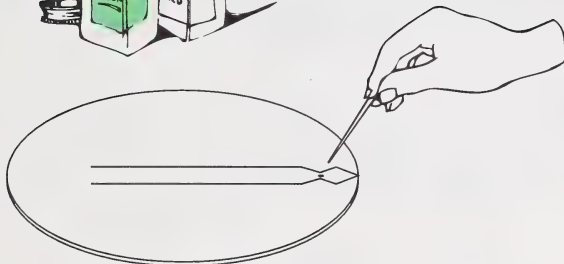
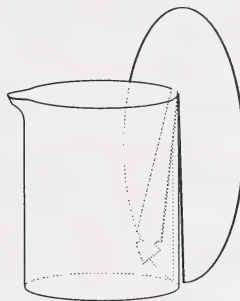
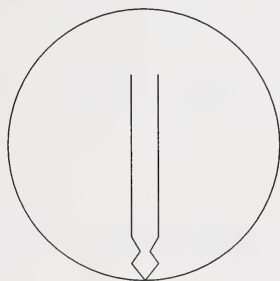
Materials

- filter paper
- 400 mL beaker or water glass
- red and green food colouring
- scissors
- water
- two toothpicks

Part A

Procedure

- Cut the filter paper as shown in the diagram. Check the length of the centre tab to make sure it will not quite touch the bottom of the beaker.



- Apply one colour on top of the other to produce only a single spot.
- Allow each spot to dry (about 20 seconds) before applying another.
- Repeat five times with each colour. Use a separate toothpick for each colour to avoid contamination.
- If necessary, sharpen the toothpick to make the smallest possible spot. Ideally the spot should be 1-2 mm or less in diameter.
- Slide the strip of filter paper into the beaker so that the tip is just above the bottom of the beaker as shown.

- Slowly add just enough water to the beaker so that only the tip of the strip is in contact with the water. Allow the water to soak up the strip until it is $\frac{3}{4}$ of the way to the top or until it stops moving. This may take at least ten minutes.
- As the water moves up the paper the pigment will be carried with it.
- Remove the strip and let it dry.

Observations

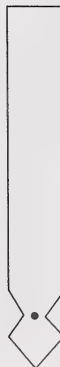
Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

13. Make a sketch of the final position of the colour bands. The bands may not be especially distinct but rather may appear as coloured areas.

Analysis and Interpretation

14. How many bands or separate colours appeared on the strip? Also notice the distance between colours.
15. Why would some of the chemicals rise faster than others? Your answer might include a prediction of solubility or molecular mass.



Check your answers by turning to the Appendix, Section 1: Activity 1.

Part B

Look over the Objective and the Materials list and do Part B if you have the appropriate items.

Objective

The objective is to determine the presence of chlorophyll and other pigments by chromatography.

Background



Chlorophyll and other plant pigments can be extracted by boiling plant material in alcohol. Alcohol can also be used as a solvent to separate these pigments by chromatography. Alcohol is toxic if swallowed. It will also irritate eyes. Alcohol evaporates easily when heated and the vapour is flammable. Alcohol should only be heated in a water bath.

Materials

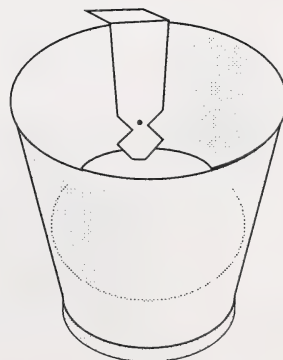
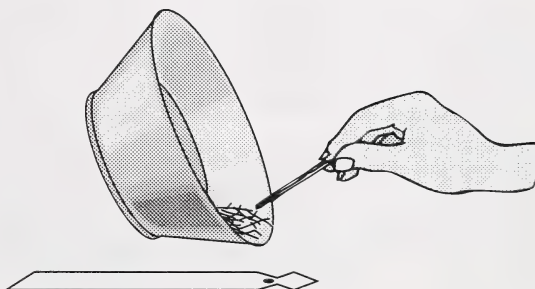
- 100 mL methanol*
 - filter paper
 - non-flame heat source
 - 400 mL beaker
 - scissors
 - toothpick
 - spoon
 - small bowl
 - fresh green plant leaves such as spinach, tomato, a leafy vegetable from the store, or house plant
- Use about two tablespoons of leaf material.

*supplied by student

Note: Methanol is available at most pharmacies.

Procedure

- Cut the filter paper as in Part A.
- Crush the plant material in the small bowl with a spoon until some juice is released.
- Add 15 mL methanol to the bowl and heat to nearly boiling. The alcohol should turn green as chlorophyll is extracted.
- Transfer ten spots of your chlorophyll extract to the filter paper with the toothpick. Remember to let the extract dry completely between applications. This is to produce a small but very concentrated spot.
- Suspend the filter paper in alcohol in the beaker as in Part A and let the alcohol soak upwards.
- Watch for any colour shadows or bands that represent pigments.



Observations

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

16. Sketch and label a diagram of the final position of the coloured pigments isolated from the plant. Match the colours to the names of the pigments if possible.

chlorophyll – green

carotenoid – yellow

xanthophyll – brown-orange



Analysis and Interpretation

17. How do you explain the appearance of two green bands?

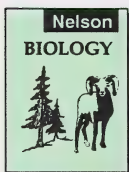
Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

Why are there different pigments in leaves? These next questions will help you discover the answer.

18. Refer to Figure 7.24 on page 191 of your text. Which colours of light are most effectively absorbed by the leaf pigments?
19. Explain the presence of the pigments other than chlorophyll.

20. Why do leaves change to a red, yellow, or orange colour in the fall?



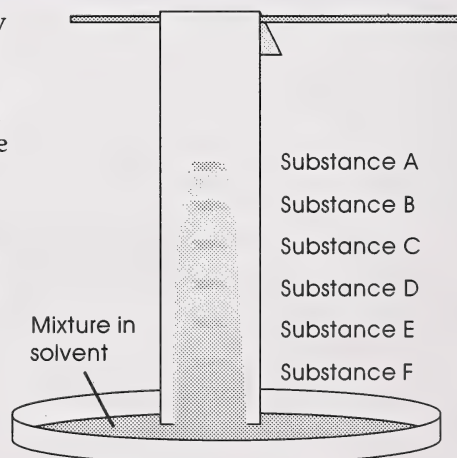
Check your answers by turning to the Appendix, Section 1: Activity 1.

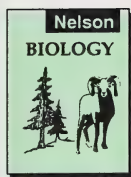
You can try some variations in chromatography by using different plants or by using other solvents instead of water. Solvents such as methanol (lock de-icer or fondue fuel) or varsol (paint thinner) may separate substances that are not water soluble.



Care must be taken using these substances. Some can be harmful if gotten on the skin or in the eyes and many are flammable and so must be kept covered.

You might be able to produce a pigment separation like this:





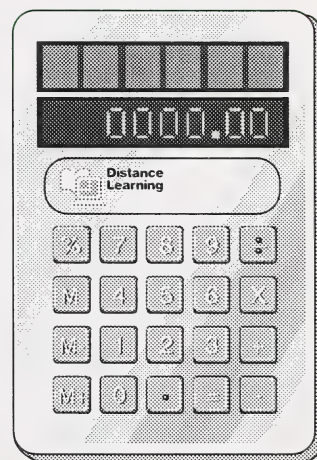
In this activity you have examined the nature of chlorophyll – the molecule that captures the energy in sunlight. You have discovered that it is sensitive to specific colours (wavelengths) of light. Check Figure 7.24 in your text. Scientists in Canada are currently trying to develop substances that will mimic chlorophyll but have not been successful yet. If scientists could manufacture an artificial chemical that behaved like chlorophyll, there would be endless applications. Can you think of some?

ACTIVITY

2 The Energy System

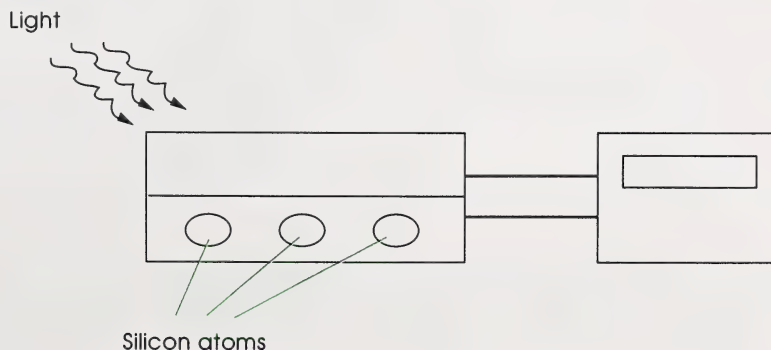
You already know that photosynthesis is a process whereby plants use water, carbon dioxide, and sunlight to produce oxygen and carbohydrates. You also know that chlorophyll makes this happen. But what do you really know about the actual process? Perhaps the best way to approach photosynthesis is to first consider a similar process in a common solar-powered device.

Have you ever used a solar calculator? How does the solar cell work? Does it work in a manner similar to photosynthesis? A solar cell contains layers of silicon atoms. When light strikes the layers, electrons are jolted away from their atoms. These electrons can generate a small electric current.

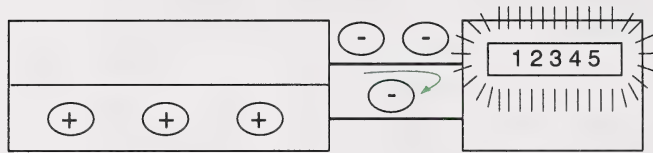
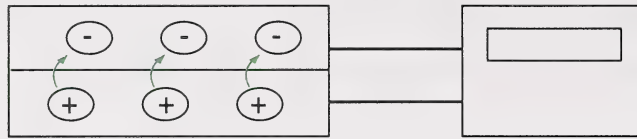


Actually three processes occur in a solar cell to convert sunlight into electricity. You might be surprised how simple it is.

- Step 1 Light is absorbed.



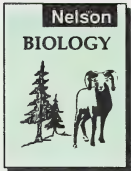
- Step 2 Electrons (negative charge) separate from a silicon atom leaving a positively charged hole.



- Step 3 The electrons flow as a current through an appliance – like the calculator – back into the positive holes.

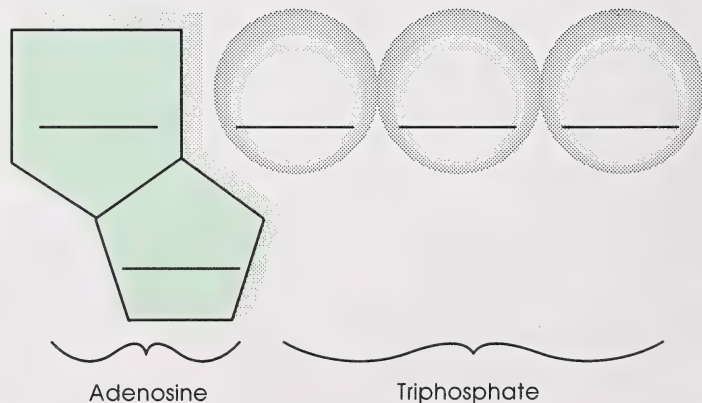
So in a solar cell, light energy really is converted into electrical energy. But plants don't produce electricity! You might ask what the connection to chlorophyll is. Chlorophyll converts light energy into chemical energy.

ATP – adenosine triphosphate



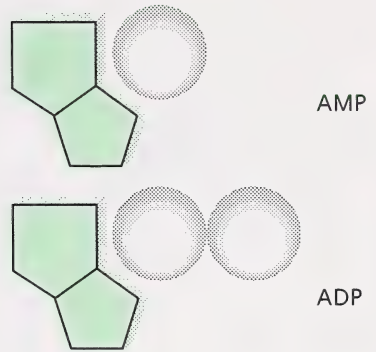
The chemical energy is in the form of a high energy bond in a unique substance called ATP. Check Figure 7.19 on page 187 in your text. Don't worry, you don't have to memorize this structure, but you should note that ATP basically consists of three phosphate molecules attached to an adenosine molecule. Adenosine is made from a sugar molecule and an adenine molecule.

1. Use the preceding information and Figure 7.19 to label this diagram.

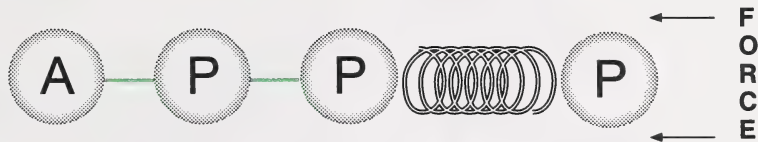


ATP starts off as AMP (adenosine monophosphate) and ADP (adenosine diphosphate).

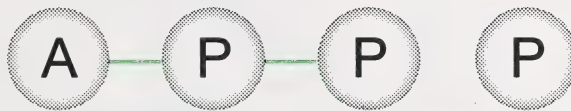
And herein lies the key to energy conversion.



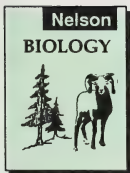
It takes energy to put the ATP molecules together and that energy is stored while the molecule stays in that form. If the ATP is broken into ADP and phosphate, energy is released.



2. Use the symbol ~ to illustrate the highest energy bond in ATP. Draw it in the following diagram.



Check your answers by turning to the Appendix, Section 1: Activity 2.



To further understand the concepts of energy storage and transformation, read pages 187 to 189 in your text and then answer the following questions.

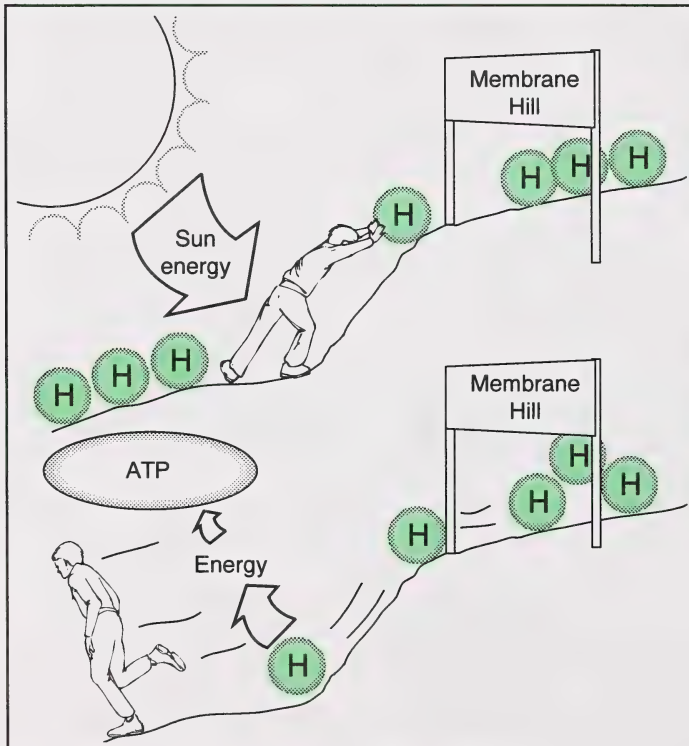
3. In an economic system, different currencies have different values. Compare the amount of energy stored in molecules of ADP and ATP to the value of silver and gold coins in an economic system.
4. After an ATP molecule has been broken into ADP and phosphate, what do you need to regenerate an ATP?

Check your answers by turning to the Appendix, Section 1: Activity 2.



Have you ever gone tobogganing? Climbing up the hill is hard work, but sliding down is fun! Energy is stored in you and the toboggan as you walk up the hill. Sliding down the hill releases the energy that you stored by your position and it is transformed into motion.

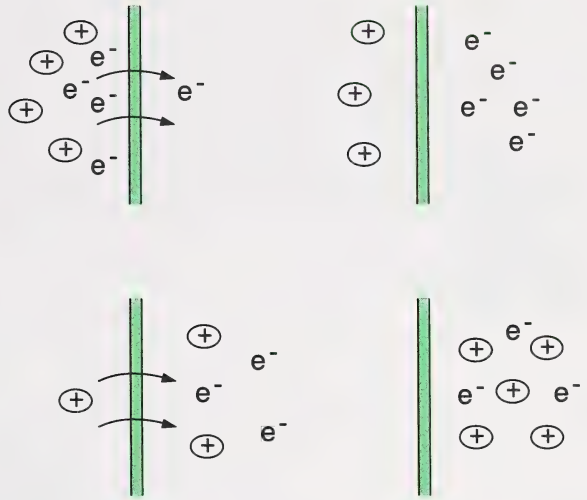
concentration
gradient –
different
concentrations of
a substance
across a barrier



The Principle

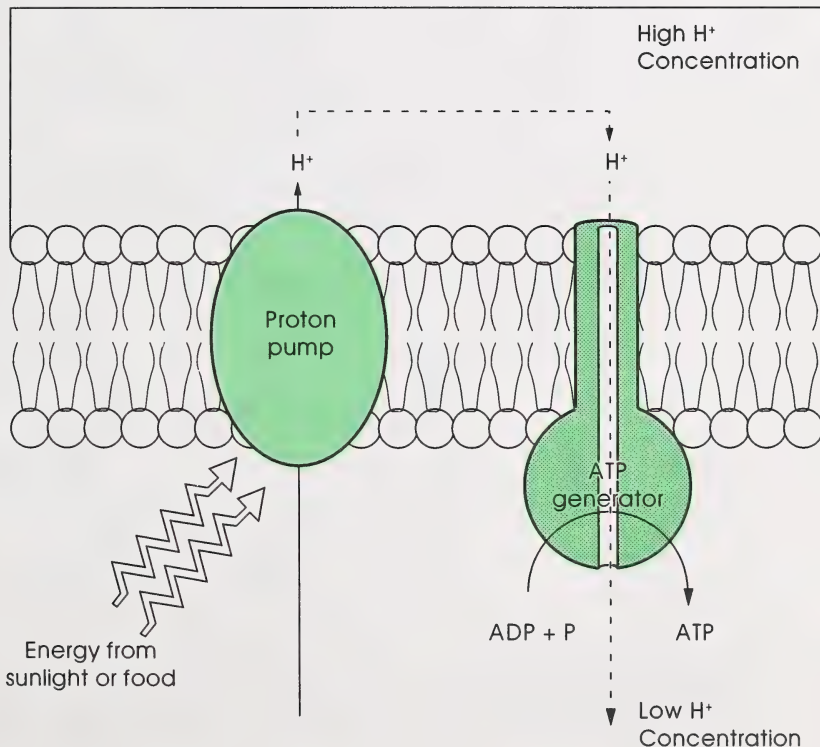
Cells generate ATP in a very similar manner. Energy is used to pump protons (hydrogen ions) across a cell membrane. A high concentration of protons on one side of the membrane establishes a **concentration gradient**. This is similar to climbing up the hill as energy must be used to do this. When these protons move back across the membrane, the energy released is used to produce ATP. The following illustration shows how this occurs.

Notice how the protons are pushed up and through the membrane first. This takes energy. Next the protons move back across the membrane and down the hill. This releases the energy.

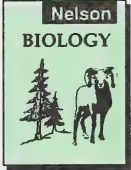


In cells the protons are first moved across the membrane by an *electron transport system*. Electrons are moved first and protons follow.

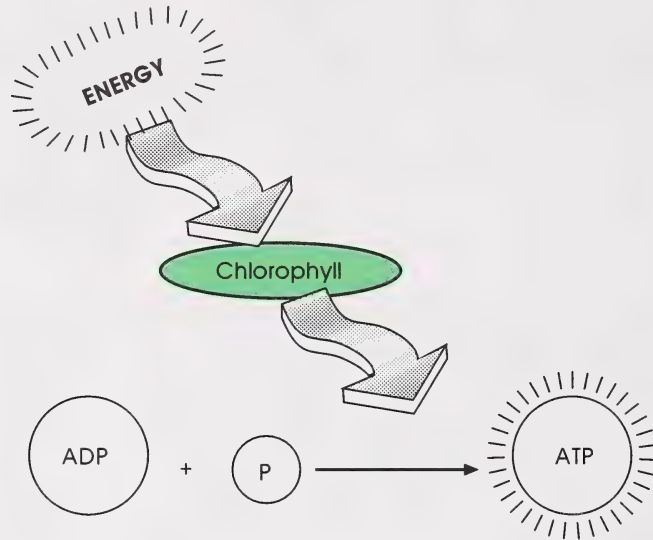
When the protons return, they pass through an ATP generator, an enzyme, which uses their energy to make ATP.



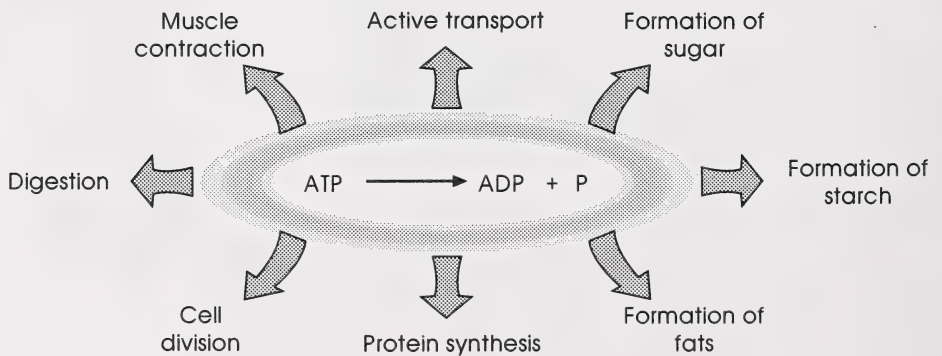
chemiosmosis –
the flow of
protons across a
membrane



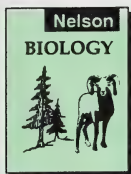
The movement of protons through this membrane is called **chemiosmosis**. Turn briefly to page 193 in your text and look at Figure 7.29. The membranes are called thylakoid membranes. They form thylakoid discs which can be seen in Figure 7.23 on page 191 in your text. The thylakoid discs are made of chlorophyll. Don't try to sort out the intricate details of photosynthesis yet. Just note that the first part of photosynthesis uses light energy to form a high energy compound called ATP. This is done by moving protons across a membrane. This is one of the functions of chlorophyll.



Once formed, ATP can be used as an energy source for a large number of biological processes. The energy is released when ATP breaks down to ADP and a phosphate molecule.



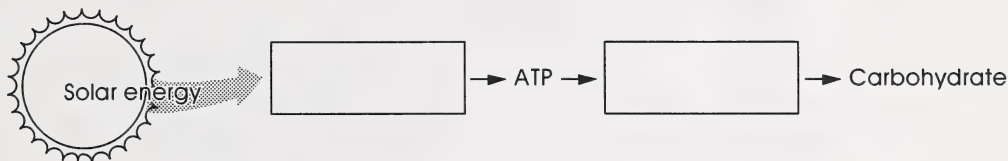
Careful here! Didn't you note earlier that through photosynthesis plants make carbohydrates and oxygen? Where does ATP fit in? Obviously a little more detail is necessary.



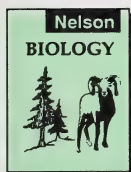
Refer back to page 190 of your text.

5. Name the two general reactions in photosynthesis.

These two reactions could be shown like this:



6. Add the reaction names to the appropriate boxes.



Start with Light-Dependent Reactions on page 192 in your text.

7. What are the clusters of light-absorbing pigments called?
 8. How does light energy affect electrons in these photosystems?
 9. What happens to this energy when the electrons return to a lower energy level?

Besides raising electrons to a higher energy level, the light-dependent reaction also affects water molecules.

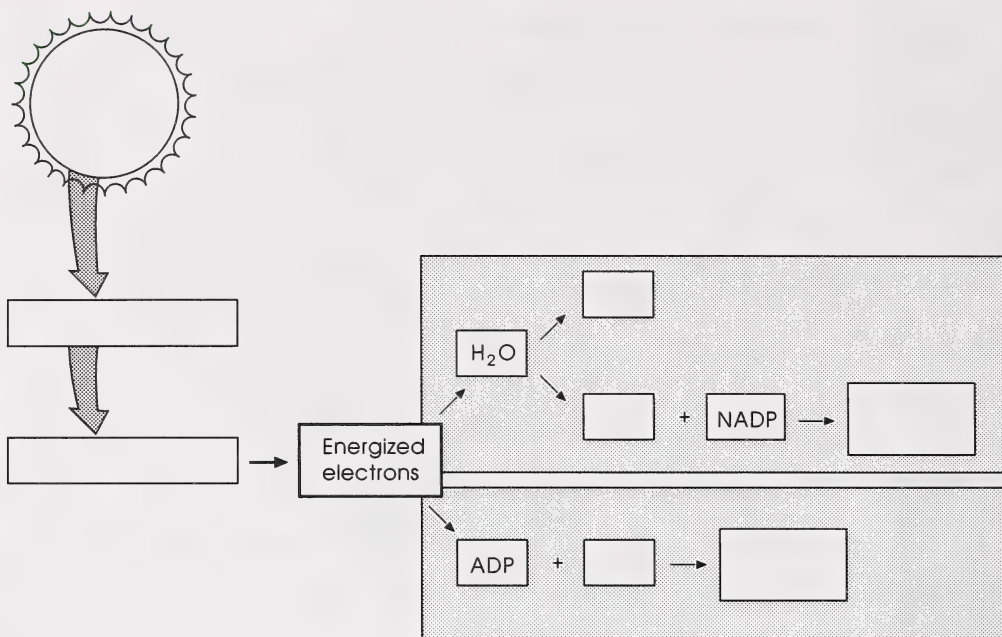
10. What products result from the photolysis of water in this reaction?
 11. What happens to oxygen produced in this reaction?
 12. Where do the hydrogen atoms or protons go from the light-dependent reaction?
 13. Use the following terms to fill in the spaces on the diagram. A couple are done for you already.

- | | |
|----------------|-----------------------|
| • ADP | • 2 H ⁺ |
| • ATP | • O (oxygen) |
| • P | • H ₂ O |
| • Chlorophyll | • NADP |
| • Solar energy | • Energized electrons |
| • NADPH | |

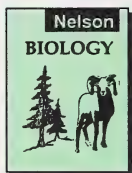
Keep in mind as you study these compounds that some are specific to certain living things. For example, chlorophyll may be found in plants, protists, and some forms of bacteria. It is not found in animals. Other compounds like ATP are common to all life forms.

Science Skills

- ☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☒ D. Analysing
☒ E. Synthesizing
☐ F. Evaluating



Incidentally, NADP or *nicotinamide adenine dinucleotide phosphate* is known as an electron carrier. Many biological molecules do this in what are called electron transport systems. Look at Figures 7.27 and 7.28 on page 193 in your text. Electron transport systems move electrons (e^-), protons (H^+), and energy in cells. During photosynthesis NADP picks up or accepts electrons, protons, and energy to form NADPH. Later the NADPH can break down and release the electrons, protons, and energy.

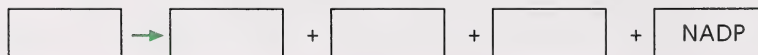


14. Fill in the following boxes to show the formation and breakdown of NADPH. Use information from the preceding paragraph.

Formation



Breakdown



Check your answers by turning to the Appendix, Section 1: Activity 2.

NADP has a positive charge and so should be written as NADP^+ . The addition of protons and electrons forms NADPH, which has no charge. Since the charge has been reduced to zero, NADPH is sometimes called **reduced** NADPH.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☒ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

15. Look at these molecules.



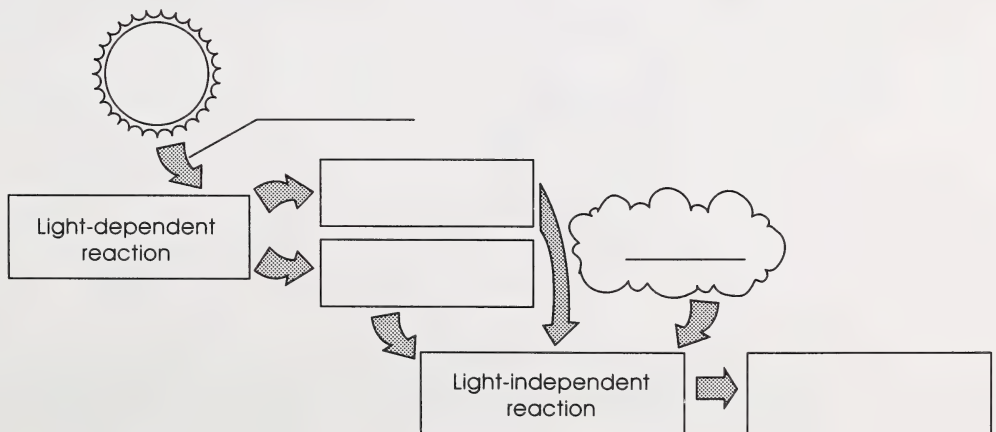
How many electrons must react with one NADP^+ and one H^+ to form one NADPH? Here's a clue, the positive and negative charges must add up and cancel each other out.

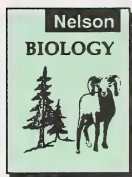
NADPH represents energy just like ATP. These energy-bearing compounds are used in the second part of photosynthesis, where carbohydrates are formed. Just so you don't lose track, answer the next two questions.

16. Where are the thylakoid membranes?
17. What are the names of the two energy-containing compounds formed on these membranes in the first step of photosynthesis?

Move on now to the Light-Independent Reactions or Carbon-Fixation Reactions on page 194 in your text. Read this passage up to the Summary on page 195.

18. Who are recognized as the co-discoverers of this part of photosynthesis?
19. Where in the chloroplast does this reaction take place?
20. Where do plants get the carbon needed for this reaction?
21. As a brief overview of this reaction, use light energy, ATP, NADPH, CO_2 (carbon dioxide), and carbohydrates to complete the following diagram.





You can see by looking at Figure 7.30 on page 194 that the light-independent reactions, or **Calvin-Benson cycle**, has some intermediate compounds.

22. Identify the four key intermediate compounds in the stroma from Figure 7.30 and write out their proper names.

23. Which intermediate compound is also a product of the Calvin-Benson cycle?

As the end product of photosynthesis, PGAL has at least three possible functions.

24. Describe three functions of PGAL using the information from page 195 of your text.

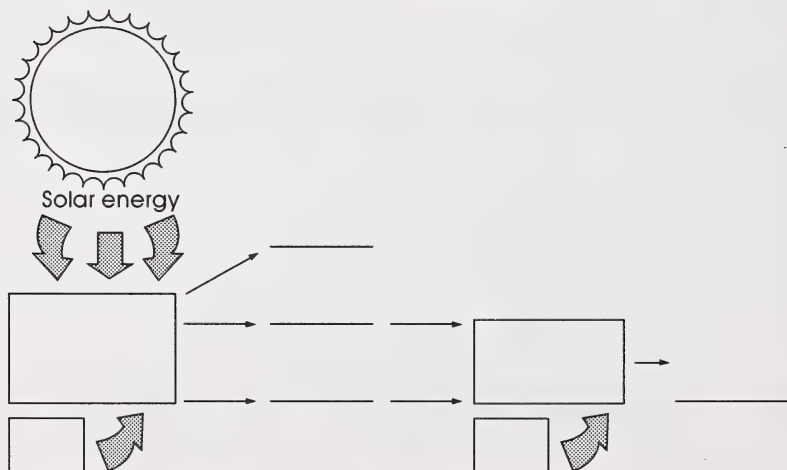
Do you remember the equation for photosynthesis at the beginning of Activity 1? Can you see now where the carbohydrate comes from?

Look at Figure 7.30 on page 194 again.

25. PGAL can be converted into glucose phosphate. Name three products that can be made from this material. All of these products would be classed as carbohydrates and would contain the energy originally captured by chlorophyll from sunlight.

26. Complete this basic diagram of the light-dependent and light-independent reactions using the terms from the following list.

- | | | | |
|----------|-------------------|---------------------|-----------------|
| • H_2O | • Light-dependent | • CO_2 | • NADPH |
| • O_2 | • ATP | • Light-independent | • Carbohydrates |



Check your answers by turning to the Appendix, Section 1: Activity 2.



If you have access to the video *Photosynthesis* (ACCESS #VC3245), watch each of the six ten-minute programs as a review.

Investigation: Investigating Photosynthesis

Objective

Determine the importance of sunlight to photosynthesis.

Background

The presence of starch can be taken as evidence of photosynthesis. Reaction between starch and iodine can provide an indicator.

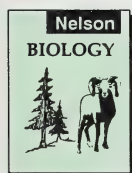
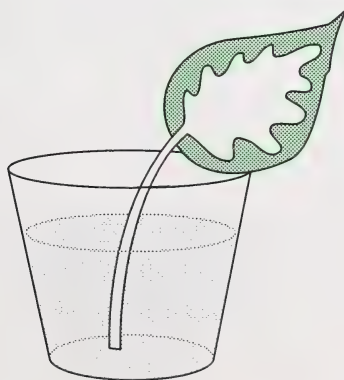
PATHWAYS

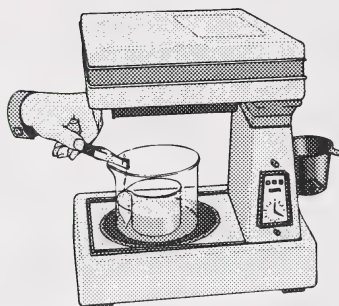
If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B. If you do not have access to the video required for Part B, do Part C.

Part A

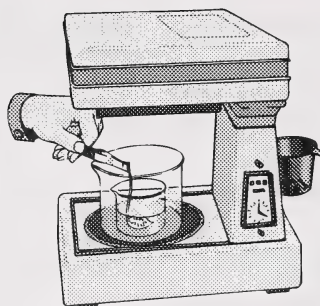
Complete the Laboratory on page 196 of your text. Read completely through the Procedure before starting the investigation. Note that one leaf from a coleus plant is to be kept in the light for seventy-two hours and another is to be kept in the dark for seventy-two hours prior to the investigation. Set the leaves in a glass of water.

Pour water through the coffeemaker first. Then place the beaker of alcohol in the hot water. Notice also that the leaves are to be dipped in boiling water first; then they are dipped in hot alcohol. Remember to use forceps. A gentle boiling of water such as passing through a coffeemaker is usually sufficient to create hot alcohol.





Dipping in water



Dipping in alcohol



Do not use an open flame. Use an electric heat source.

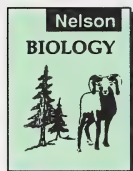
Analysis and Interpretation

27. Answer the Laboratory Application Questions 1 to 6 on page 196 in your text.

Part B



Watch this exact investigation on the video *Experiments in Photosynthesis* and then answer the Laboratory Application Questions on page 196 in your text.



Part C

Read over the laboratory investigation on page 196 in your text. Using this description, answer the Laboratory Application Questions 1, 4, 5, and 6.

Check your answers by turning to the Appendix, Section 1: Activity 2.

ACTIVITY

3

Herbicides in Your Garden

Knowledge of photosynthesis enables humans to play a role in the chemistry of life.

Medicines, poisons, pesticides, and herbicides affect living organisms. The most common mode of action is the interference of a biochemical pathway. This means that somewhere along a series of chemical reactions, at least one of the steps is altered. A common herbicide that functions in this manner is **sulfanyl urea**. This herbicide acts by blocking one of the steps of photosynthesis. This is interference with an actual living process that took millions of years to evolve.

Do you have any concerns about the use of herbicides? Many scientists, farmers, and homeowners have concerns. They are concerned with the chemical effect on the plant they're trying to kill, on other plants close by, on animals living in the area that feed on the plants, and finally with the effect these chemicals may have on people. This problem is very complex with a number of very significant concerns. In this activity you will explore these concerns and you will gain an appreciation of the various viewpoints of the herbicide issue.

Examine the following illustration of what a biochemical pathway looks like and how a herbicide can block this pathway.

A and **B** are the initial reactants in the pathway. The final product of the overall reaction is Substance **I**. In order for the biochemical pathway to reach completion, all steps must proceed in order and without interference.



A chemical can be used to block one of the steps. The biochemical pathway, which is essential for photosynthesis, would be stopped.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

1. A chemical herbicide (XYZ) destroys Reactant D found in the preceding pathway. Which product would first be prevented from being produced?
2. A chemical herbicide (KJK) prevents Reactants E and F from joining together. Which product would first be prevented from being produced?
3. Which chemical, XYZ or KJK, could be used to prevent the growth of a certain weed that required final product Substance I in order to survive? Why?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Science Skills

- ☒ A. Initiating
- ☐ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

Imagine you have developed a herbicide that acts in a similar manner to XYZ. In its pure form the herbicide is very concentrated and cannot be applied directly due to the chemical's instability. In its pure form it vapourizes before it can be absorbed. The herbicide must be diluted with water to lower its concentration. Just a few millilitres of XYZ mixed with one litre of water will produce an effective herbicide. You are not sure how many millilitres between zero and ten should be applied. Due to environmental and economic concerns, you want to apply the least amount while still maintaining effectiveness.

4. State the problem that must be overcome with the use of your new herbicide.

You decide to add between 0 mL and 10 mL of XYZ per litre of water to a plot of weeds to discover the maximum effectiveness.

5. Make a list of controlled variables that must be adhered to in order to make the experiment a success.

Check your answers by turning to the Appendix, Section 1: Activity 3.

6. The following data was obtained. Use your own graph paper to plot the data, using a best fit line, onto a graph.

DILUTION RATE (mL/L)	SURVIVAL RATE (%)
0.0	100
0.5	72
1.0	61
1.5	50
2.0	38
2.5	25
3.0	5
3.5	0
4.0	0
4.5	0
5.0	0
5.5	0
6.0	0
6.5	0
7.0	0
7.5	7
8.0	28
8.5	39
9.0	55
9.5	55
10	55

7. What is the range at which the dilution rate of the herbicide is most effective? Why?
8. Would applying pure herbicide be the most effective method of controlling weeds?
9. Why would the survival percentage of weeds increase when the dilution factor reached 7.5 mL/L?

10. Which dilution rate would you recommend be used? Explain.

Check your answers by turning to the Appendix, Section 1: Activity 3.

The incorrect use of a herbicide can be harmful to your health or the health of the environment. Its effectiveness may be reduced necessitating further applications. Always follow the directions carefully. Wear protective clothing as many herbicides easily pass through the skin. Wear eye protection. Avoid breathing vapours or dust particles and do not apply more herbicide than recommended.

In a biosphere designed for living things, herbicides represent a dead end.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

PATHWAYS

If you have access to the video, *Photosynthesis*, do Part A. If you do not have access to this video, do Part B.

Part A



The process of photosynthesis can be a little confusing. Watch the first program – *Seeing the Light* – of the video, *Photosynthesis*, to help you understand the key points presented in this section. Answer questions 1 to 4 as you watch the video. If you miss an idea, stop the tape since the questions match the order of topics in the program.

1. Fill in the blanks to complete this statement: In photosynthesis, _____ and _____ combine to form _____, a _____.
2. Draw a sketch to show the idea that solar energy is being converted to chemical energy. Be sure to include chlorophyll.

3. Draw arrows from the reactant side to the products side to illustrate how the CO_2 and H_2O are used in photosynthesis.

REACTANT



PRODUCTS



4. Photosynthesis can be grouped into two sets of reactions – the _____ reaction and the _____ reaction. In the first step _____ is broken using _____. The second step is where _____ is made.

Check your answers by turning to the Appendix, Section 1: Extra Help.



Watch the second program *Absorbing the Light* and answer questions 5 to 7 as you go through the video.

5. Why is it that leaves look green?
6. How do you know then that chlorophyll uses other colours of light best?
7. The light energy that reaches a chlorophyll molecule causes it to change by _____.

Check your answers by turning to the Appendix, Section 1: Extra Help.

8. Match the terms in Column I with the correct statement in Column II.

Column I

- a. heat
- b. autotroph
- c. heterotroph
- d. photosynthesis
- e. respiration

Column II

- i. a reaction that stores solar energy in glucose
- ii. an organism that cannot make food with light
- iii. the energy lost in a transformation
- iv. an organism that makes its own food
- v. a reaction that releases the energy in food

9. In photosynthesis light energy is used to split water into hydrogen and oxygen and to make ATP from ADP and phosphate (P). Later the energy stored in ATP is used to combine hydrogen with carbon dioxide to form carbohydrates. Construct a diagram that shows this flow of energy.

Part B

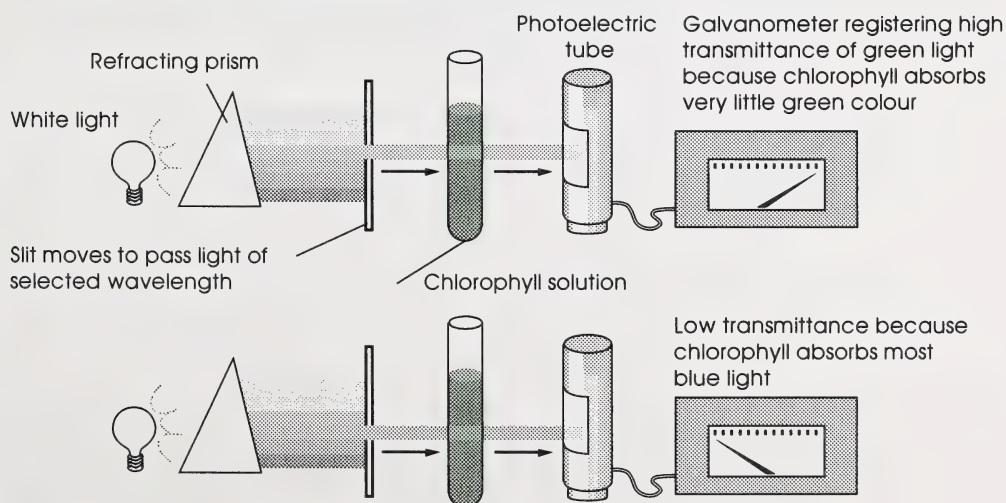
Refer to pages 189 through 195 in your text; then answer questions 1 to 9 in the Extra Help, Part A. Check the answers in the Appendix if you have difficulty.

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Do any or all of the following activities.

- The experiment previously described by Engelmann was a simple and excellently designed experiment used to determine which wavelengths of light plants absorbed. Scientists today have developed a much more sophisticated device to measure the same thing. The device is known as a **spectrophotometer**. If you break the word down you can decipher what it does. *Spectro* relates to the various colours of the spectrum (wavelengths) or colours of the rainbow. *Photometer* refers to a device used to measure light. The device is used in determining the colour that plants absorb for photosynthesis. You should be able to deduce that a spectrophotometer is used to measure the proportions of light of different wavelengths which are transmitted through a solution of plant pigments.



In a spectrophotometer light is broken down into its various colours by a prism. One by one the colours are shone through a sample of chlorophyll in order to determine which wavelengths will be absorbed best. If very little light is absorbed by the pigment, most of the light is transmitted and is measured as a high reading. In contrast, if most of the light is absorbed or very little is transmitted, a low reading will register.

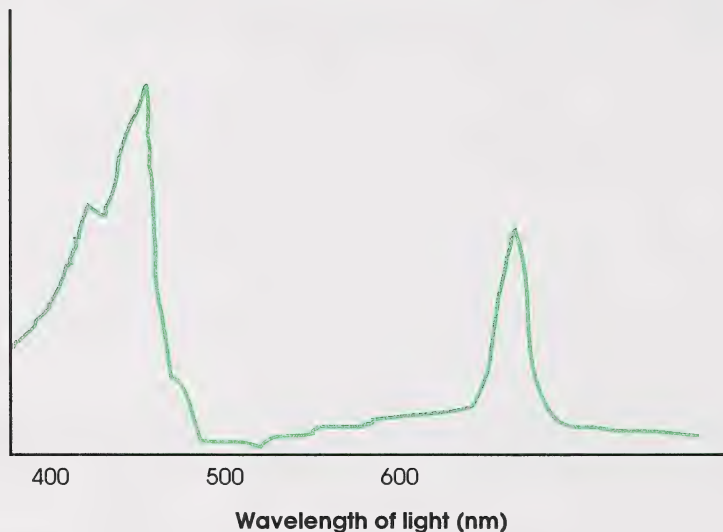
Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

- a. What is a spectrophotometer used to measure?
- b. If a spectrophotometer reading is high, has the sample tested absorbed or transmitted most of that specific wavelength of light?

Remember that plants contain various pigments which are able to absorb a particular wavelength of light and then use it through photosynthesis to produce glucose. By studying the major pigment chlorophyll, you can learn how a spectrophotometer works.

ABSORPTION SPECTRUM OF CHLOROPHYLL A AS MEASURED BY A SPECTROPHOTOMETER



Use the preceding graph to answer the following questions.

- c. Which wavelength and colour of light does chlorophyll *a* absorb the most of?
- d. Which wavelength and colour of light does chlorophyll *a* absorb the least of?
- e. Based on the absorption spectrum, what colour are leaves that contain a high level of chlorophyll *a*?

Check your answers by turning to the Appendix, Section 1: Enrichment.

2. Scientists from the planet of Sigma Tau wish to have their spectrophotometer results analysed by an Earth scientist knowledgeable about photosynthesis. You have been chosen to interpret their results.



THE RESULTS OF AN ANALYSIS OF A SOLUTION OF PLANT PIGMENTS FROM SIGMA TAU

	WAVELENGTH OF LIGHT (nm)						
	400 violet	450 blue	500 green	550 yellow	600 orange	650 red	700
Absorbance of light (%)	30	35	60	10	15	30	45

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

- a. Use your own graph paper to graph the results of the spectrophotometer from the leaves of Sigma Tau.
- b. Which wavelengths of light are best absorbed by the leaves of Sigma Tau? Why?
- c. What colour would the leaves of Sigma Tau be?

Check your answers by turning to the Appendix, Section 1: Enrichment.

If you have access to a spectrophotometer at your school, at a university or college nearby, or even at a local company, contact these places and see if you can visit to further explore the use of this amazing machine. Watch for an opportunity to visit any research institution during an open house.

Use of herbicides occurs in government, industry, the private sector, agriculture, and the military. Herbicides are biocides, that is, they kill living things. More specifically, herbicides kill plants. However, they may also be harmful to soil bacteria and animals.

You might have had the opportunity in the past to use a lawn herbicide. Did you read the label beforehand? Did you take all necessary safety precautions? Were you aware of the environmental and health hazards associated with the use of the chemical? By reading the following article on lawn herbicides you will be able to answer these questions in relation to the herbicide 2, 4-D.

Lawn Herbicides

(Weed and feed preparations, weed bars, numerous other weed and dandelion killers, soil sterilants)

Chemical Group

Phenoxy acid.

How it Works

A phenoxy acid herbicide such as 2, 4-D is absorbed into a plant through any plant surface and transported by the circulatory system to all parts of the plant. It kills by causing abnormal cell growth that blocks the movement of liquids and nutrients throughout the plant. The roots starve and the plant dies.

Uses

2, 4-D and its cousin compounds are toxic to broadleaf plants such as dandelions, thistles, and ragweed. They are mixed with fertilizers in the popular weed and feed products and are also sold on their own for domestic use as tablets, solids, granules, pressurized products and solutions used by lawn maintenance companies.

Restrictions on Use

These herbicides should not be stored or used near foodstuffs.

Environmental Hazards

Phenoxy acid herbicides such as 2, 4-D are relatively non-toxic to birds and mammals compared to many other pesticides. They may, however, have "sublethal" effects: injury that is not obvious but that shows up later. Research has not yet provided a conclusive answer as to whether such effects exist.



Phenoxy acid herbicides will persist on your lawn for one to three months, depending on which compound is used and the rate at which soil bacteria break it down. Birds and mammals may therefore be exposed to the herbicide for a long period after it has been applied. Except for severe infestations, spot apply lawn herbicides rather than applying them to the entire lawn.

Because these herbicides can drift away during spray operations and contaminate nearby areas, particular care should be taken when applying them near desirable plants. They should not be sprayed when winds are greater than 15 km/h.

2, 4-D and other phenoxy acid herbicides should not be allowed to contaminate water supplies. Waste materials and containers should not be disposed of near water supplies, nor should waste materials be emptied into sewer drains.

Health Hazards

Phenoxy acid herbicides have slight to moderate toxicity if taken by mouth and are unlikely to cause poisoning unless deliberately swallowed. They are slightly toxic by skin contact. Gardening or rubber gloves should be used for handling them, and shoes should be worn when walking on newly treated lawns.

If a phenoxy acid herbicide is swallowed, symptoms of poisoning may include stomach cramps, vomiting, salivation, diarrhoea, mental confusion, convulsions, and muscular incoordination. The pulse may be rapid and blood pressure low. Medical attention should be obtained immediately. First aid treatment consists of inducing vomiting when any form of phenoxy acid herbicide for domestic use (check the label) has been swallowed. However, if the label says "emulsifiable concentrate" (true only for a commercial product), vomiting should not be induced.

Safety Precautions

Pesticides are poisons, otherwise they wouldn't kill. They should be handled with care:

- ☐ Consider using nonchemical methods of controlling weeds. See *Alternatives to Pesticides* in this fact sheet series.

- ☐ Read the label before using, follow directions, and don't exceed the rate recommended.
- ☐ Mix pesticides outside in a wind-sheltered area, not in an enclosed space.
- ☐ Don't inhale dust or spray.
- ☐ Keep children away from pesticides.
- ☐ Don't smoke or eat while using a pesticide. Wash hands with soap and water immediately after the job is finished.
- ☐ Never reuse pesticides in anything but the original containers.
- ☐ Dispose of pesticide containers by delivering them to a toxic round-up centre.



For more information on the proper use of pesticides and alternatives to their use, please see the other fact sheets in this series:

- ☐ Using Malathion Safely
- ☐ Using Dimethoate Safely
- ☐ Using Diazinon Safely
- ☐ House and Garden Aerosols
- ☐ Pesticides: Use Them Safely
- ☐ Alternatives to Pesticides
- ☐ Non-Pesticidal Control of Insects
- ☐ The Pros and Cons of Pesticides
- ☐ A Safe Insecticide for Caterpillars
- ☐ Wood Preservatives – An Overview

All are available in both English and French. Aussi disponible en français.



For further information
Environment Canada offices in

Edmonton	(403) 468-8001
Regina	(306) 780-6464
Winnipeg	(204) 983-2961
Yellowknife	(403) 873-3456

Provincial environment departments, or call the Agriculture Canada pesticide information number: 1-800-267-6315.

ENVIRONMENT CANADA

3. Answer the following questions based on the article on lawn herbicides.
 - a. How does 2, 4-D kill the plant?
 - b. List two common plants that 2, 4-D effectively kills.
 - c. What restrictions should be followed when using 2, 4-D?
 - d. What effect can 2, 4-D have on birds and mammals?

- e. Since 2, 4-D can persist on the lawn for a couple of months after it has been applied, what is the preferred method of application?
- f. Why should herbicides not be applied on a windy day?
- g. Waste material and empty containers must be disposed of appropriately to avoid contamination of water supplies. Where should this material be put for disposal?
- h. List two safety precautions that should be adhered to when applying a herbicide.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Make sure you call the Environment Canada offices if you require further information and receive all the facts prior to using any chemical so that you won't have to use the first aid information.

Conclusion

In this section you have discovered the details of photosynthesis. Sunlight travels down to Earth and is absorbed into the chlorophyll of leaves. Glucose and starch are produced. Energy is stored for later use by the plant or it is made available for heterotrophs providing them with energy essential for all of their activities.

50

Section 1 Assignment: Sunlight – Beam It Down

Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

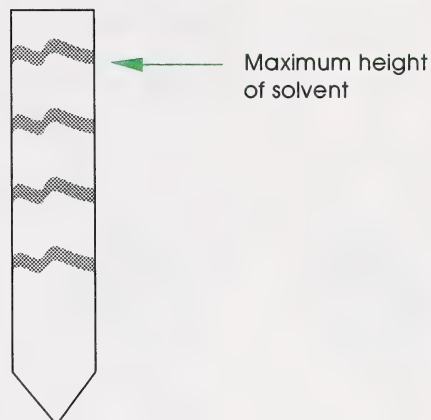
Biology 20 – Module 5	Section 1 Assignment	Page #	Name and ID#
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Be sure to write legibly. Leave a wide left margin and number all of your pages.

1. Explain the role that chlorophyll plays as a vital link in maintaining the biosphere. (2 marks)
2. As a technician in a lab you have been asked to identify the various compounds in a solution. You performed a paper chromatography analysis and obtained the following results. (4 marks)

a. How many compounds were you able to separate with the solvent used? Explain.

b. In a few sentences, discuss why this separation occurs.

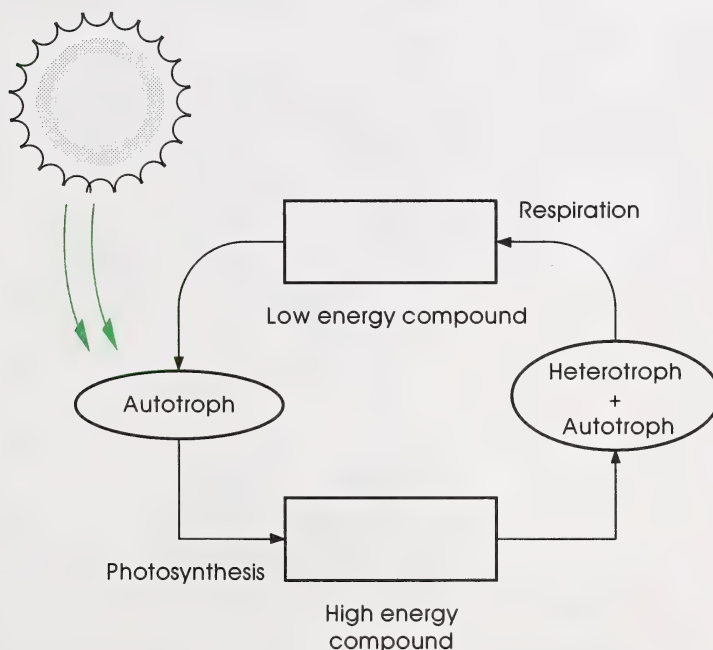


Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

3. You have been asked to design a greenhouse to grow plants for your community; One of the specified requirements is that the glass that would transmit green-coloured light be green. Use the knowledge that you gained in this section to explain the effects of this decision on the ability of the plants to photosynthesize. (2 marks)

4. a. Complete the following chart using compounds that have a low amount of energy or a high amount of energy. (2 marks)



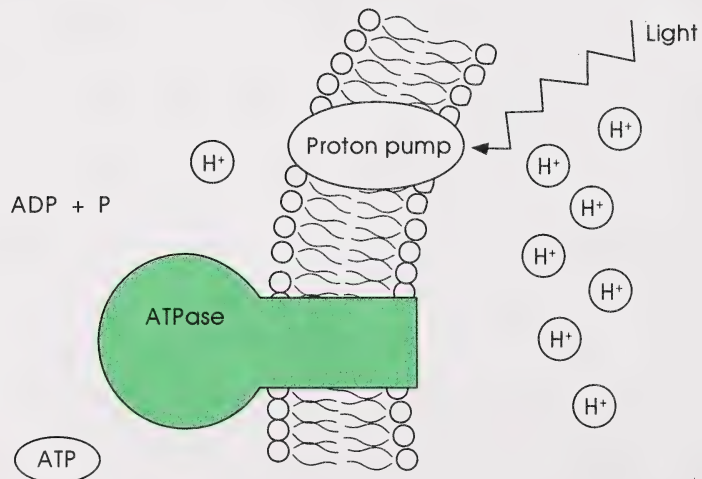
b. Discuss why autotrophs and heterotrophs both undergo the process of cellular respiration while only autotrophs are capable of photosynthesis. (2 marks)

5. Match the terms in Column I with the best definition in Column II. (10 marks)

Column I

Column II

- | | |
|----------------------|--|
| a. endergonic | (1) an energy storage molecule in living cells |
| b. exergonic | (2) the movement of protons across a membrane generating ATP |
| c. chemiosmosis | (3) energy required to initiate a chemical reaction |
| d. activation energy | (4) a reaction that liberates energy |
| e. ATP | (5) a reaction that requires energy |
6. a. Which molecule holds more energy, ADP or ATP? Explain. (2 marks)
- b. When is the energy from an ATP molecule released? (2 marks)
- c. Compare the energy value of ATP and ADP to the value of gold and silver coins. (2 marks)
7. Complete the following diagram by using arrows to indicate the direction of movement of protons (hydrogen ions) when they cross a membrane during the synthesis of ATP. (2 marks)



8. List three uses for ATP in cells. (2 marks)

Science Skills

- ☐ A. Initiating
☐ B. Collecting
☒ C. Organizing
☒ D. Analysing
☒ E. Synthesizing
☒ F. Evaluating

9. Students placed two leaf cuttings in a glass of water and left them in a dark closet. After three days they placed one of the cuttings in a 5% glucose solution and returned to the dark closet. Twenty-four hours later a starch test was performed on a leaf from each of the cuttings. **(6 marks)**

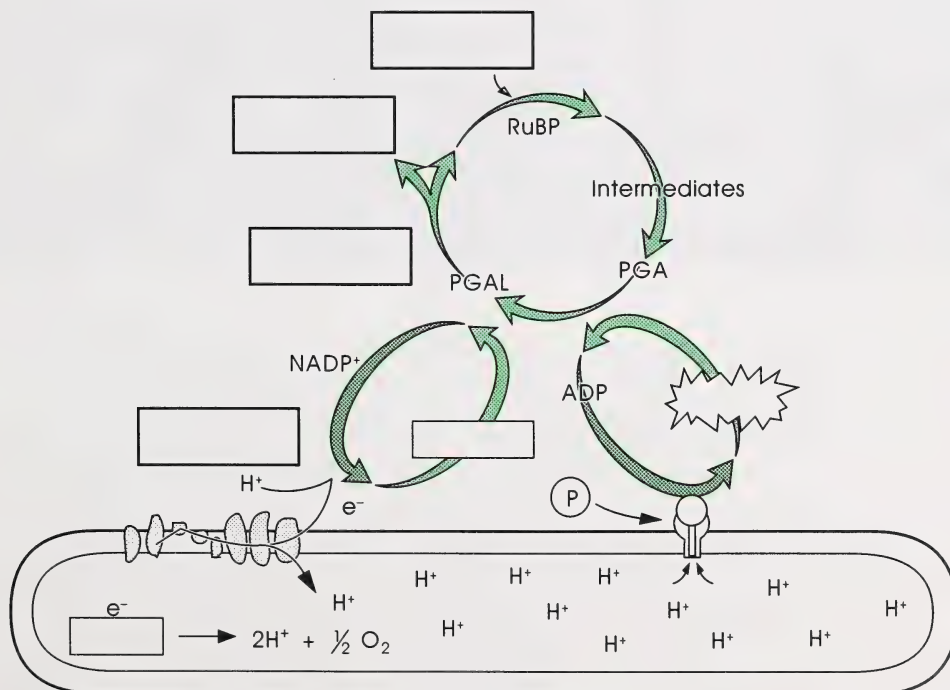
- Write a problem for this experiment. Be sure to describe the manipulated and responding variables.
- Predict the results of this experiment by drawing, labelling, and shading the leaves. Provide a reason for your decision.
- Identify two variables that need to be fixed or controlled to insure that the results are reliable. Explain.



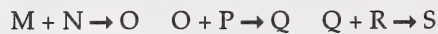
10. In what manner are solar cells and the action of chlorophyll similar? **(2 marks)**

11. Use the following list to fill in the blanks on the diagram which summarizes the process of photosynthesis. **(2 marks)**

- Glucose
- ATP
- NADPH
- Calvin-Benson cycle
- CO₂
- Light reaction
- H₂O



12. What happens to the CO_2 and H_2O that plants absorb from the surroundings during photosynthesis? **(2 marks)**
13. ATP that is produced in the light reaction is vital to photosynthesis. Describe the role of ATP in photosynthesis. **(2 marks)**
14. The electron transport system accepts the energized electrons from chlorophyll. What happens to the energy that these electrons contain? **(2 marks)**
15. The following diagram shows a reaction pathway that produces part of the chlorophyll molecule.



Explain how a herbicide that blocks the reaction that produces Substance Q is capable of killing a plant. **(2 marks)**

ATP: The Energy in You



WESTFILE INC.

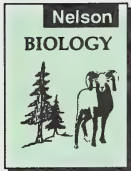
Apples on a tree are a perfect example of the results of photosynthesis. Carbon dioxide, water, and solar energy have been turned into carbohydrates. Why should an apple tree produce apples? The answer lies in the seeds. Seeds will use the energy stored in the apple to start a new apple tree. They won't do it by photosynthesis though. While energy went into the apples by photosynthesis, it can only come out by respiration.

In this section you will study the basic chemistry of respiration. You'll also explore the abilities of athletes to use energy and the effects of toxins such as hydrogen sulphide on these living processes.

ACTIVITY

1

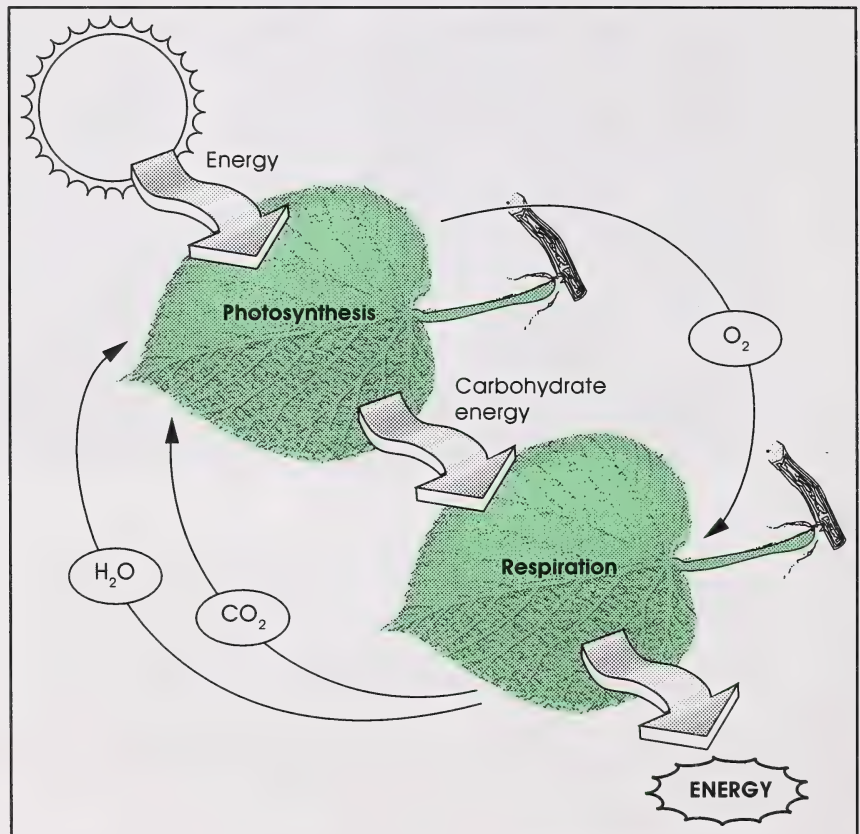
Energy from Cellular Respiration



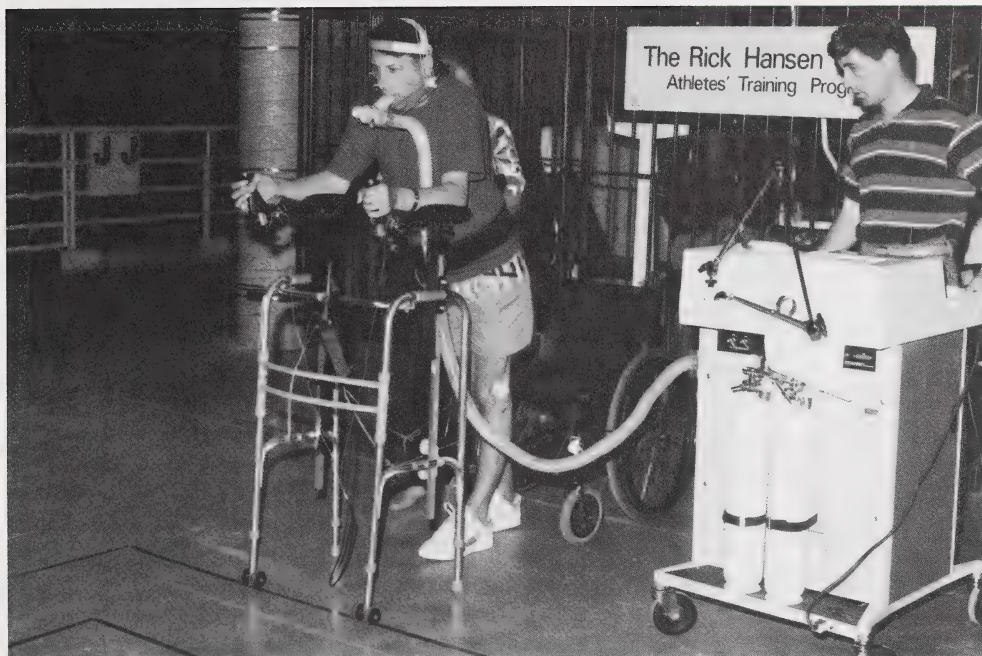
Turn to page 197 in your text and carefully look at the title. Note that cellular respiration occurs in both animals and plants. That's right, plants use photosynthesis to store energy in glucose, but they use respiration to get the energy out. Read the definition of respiration in the glossary in your text on page 620. Notice that it doesn't mention plants or animals. This definition applies to all living cells.

It was thought that plants use photosynthesis and animals use respiration to live. However, this isn't the latest idea.

1. Study this diagram. What is the latest idea about photosynthesis and respiration? Look closely at the diagram.



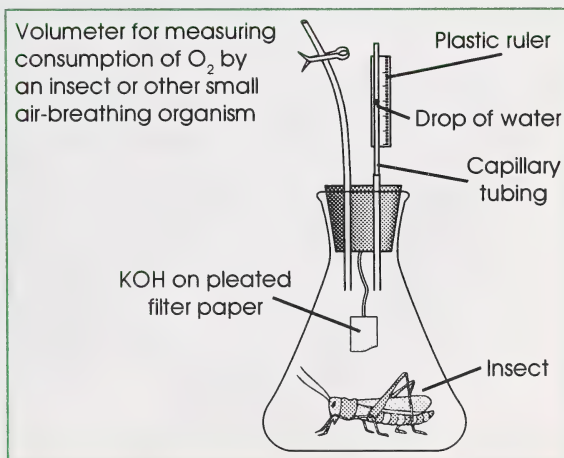
2. Besides carbohydrates, what other substance is essential for respiration?



1

The complicated apparatus in the photograph is being used to determine the oxygen consumption of the subject. If you know an organism's rate of oxygen consumption you can determine its need of oxygen for respiration. This apparatus can be simplified as shown in the diagram.

A volumeter like this measures oxygen consumption. Assuming that this is a closed apparatus and that the KOH absorbs any CO_2 produced by the insect, answer the next question.



3. As the insect in the flask uses oxygen, the water drop in the tube will move. Explain which way the drop moves and why. Imagine yourself in an apparatus like this. Would it still work?

¹ Photo courtesy of University of Alberta's Rick Hansen Centre. This individual with quadriplegia is shown using Functional Electrical Stimulation (FES) for walking. He is being supervised by Dr. Garry Wheeler, the Centre's Research Coordinator. This work is taking place in collaboration with Dr. Richard Stein, Division of Neuroscience established through the Medical Research Council of Canada.

The information in the following table provides a comparison between the oxygen consumption and the size of the animal.

ANIMAL	MASS (kg)	OXYGEN CONSUMPTION ($\text{mm}^3 \text{O}_2/\text{g/h}$)
Mouse	0.020	850
Rabbit	1.5	490
Dog	15	310
Human	70	205
Horse	750	106
Elephant	3800	80

- Use the information from the data table to prepare a line graph that illustrates the relationship between mass and metabolic rate.
- How many times more oxygen does 1 g of mouse use compared to 1 g of elephant?
- What level of oxygen consumption would you expect an infant to have? Explain.
- Use the graph to estimate your oxygen consumption per gram.
- Using this data, write a conclusion based on comparing the mass of the organism and the amount of oxygen consumed.

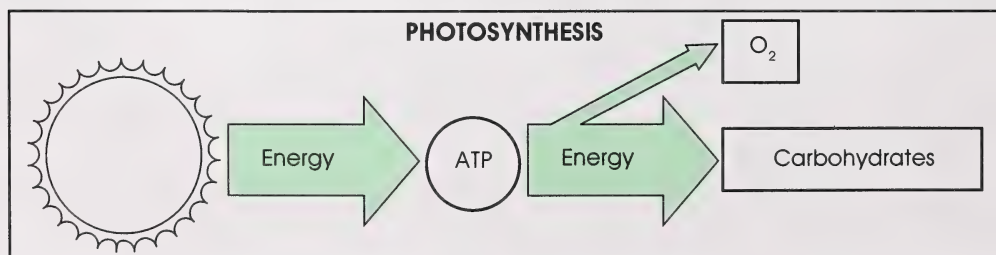
Science Skills

- ☒ A. Initiating
- ☐ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

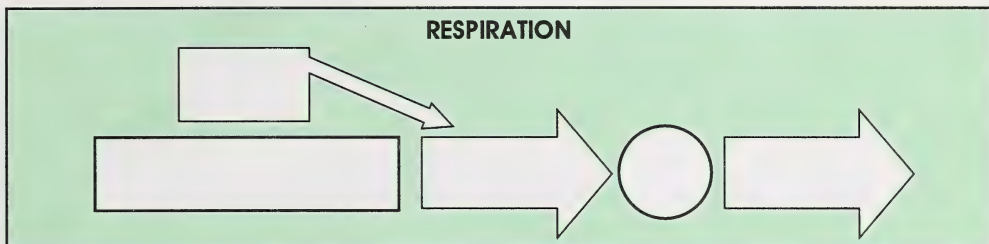
Check your answers by turning to the Appendix, Section 2: Activity 1.

So what's the connection? Is oxygen the key to respiration? The answer is both yes and no. Think back for a moment about photosynthesis. Chlorophyll uses solar energy to split H_2O into H^+ , e^- , and oxygen. The H^+ and e^- are pumped across a membrane to produce a concentration gradient. Later, by chemiosmosis, this energy is used to make ATP. Finally the energy in ATP is transferred to carbohydrates like starch and glucose.

Look at this diagram and notice the position of ATP.



9. Redraw this diagram to represent respiration by putting the correct substances back in their boxes. Notice the direction of energy flow.



10. Read the definition of respiration in the right hand column on page 197 in your text. Copy this definition in your notes.

ATP is the energy currency used by cells. At this moment you are using a tremendous amount of energy. Do your cells need a large amount of ATP? Yes, they do.

An average person will produce about 8 kg of ATP per hour.

That's 70 000 kg of ATP per year!

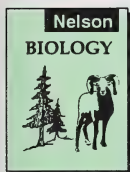
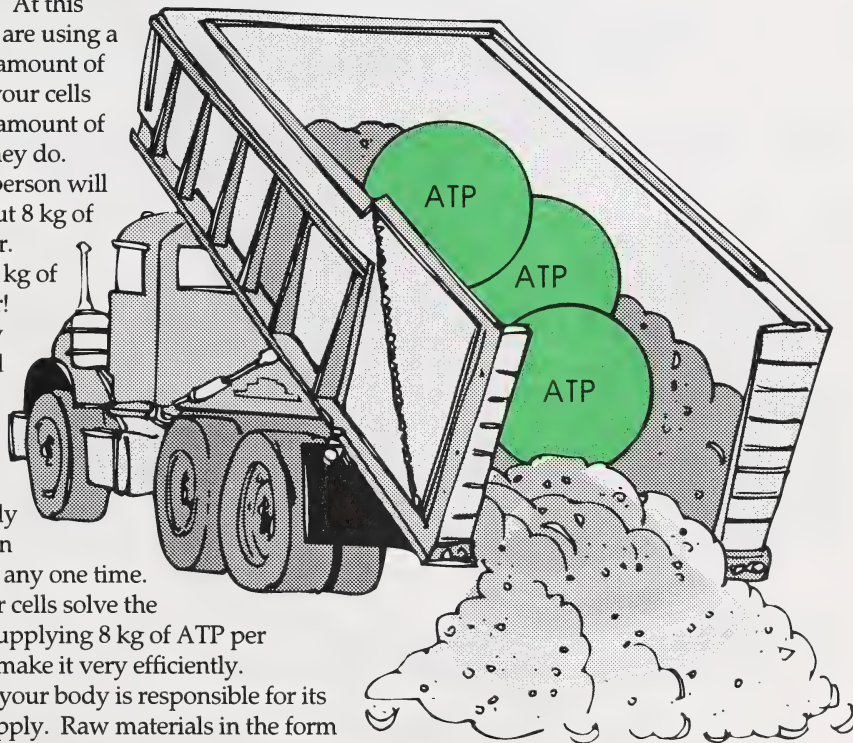
You certainly can't carry all that around with you.

In fact, you only have approximately 50 g of ATP in your body at any one time.

How do your cells solve the problem of supplying 8 kg of ATP per hour? They make it very efficiently.

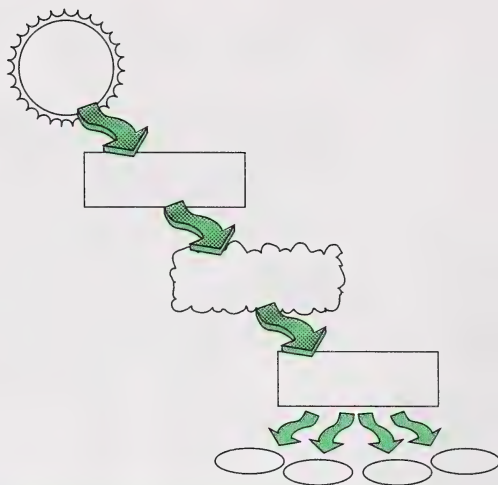
Every cell in your body is responsible for its own ATP supply. Raw materials in the form of glucose and oxygen are supplied to each cell and the ATP is generated using these substances.

ATP is generated very rapidly but it is also being constantly used up. Remember this for use later in the module.



11. Use these terms to label the following diagram and create a total energy picture.

- ATP
- Photosynthesis
- Respiration
- Carbohydrates



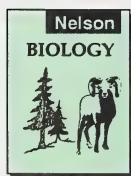
Check your answers by turning to the Appendix, Section 2: Activity 1.

So, exactly what happens in the respiration box? Or, as a student in biology, how much do you need to know?

ACTIVITY

2

Respiration: The Process



It's now time to read page 197 in your text. Read through cellular respiration and then answer the following questions.

1. Identify the various sources of energy available to animals. List these in order from the first to the last sources used.
2. What is the most common energy storage component in plants?
3. Of the total chemical energy available in these sources, what percentage can be used to make ATP as opposed to the percentage released as heat in respiration?
4. In mammals and birds, the heat of respiration is not just a waste product. What useful purpose does it serve?

Check your answers by turning to the Appendix, Section 2: Activity 2.

PATHWAYS

If you have access to the video series, *Cellular Respiration*, do Part A.
If you do not have access to this video, do Part B.

Part A



View the video *The Cell and Energy* from the *Cellular Respiration* Series and answer questions 5 to 12. Stop the tape and review an idea whenever it is necessary.

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☐ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

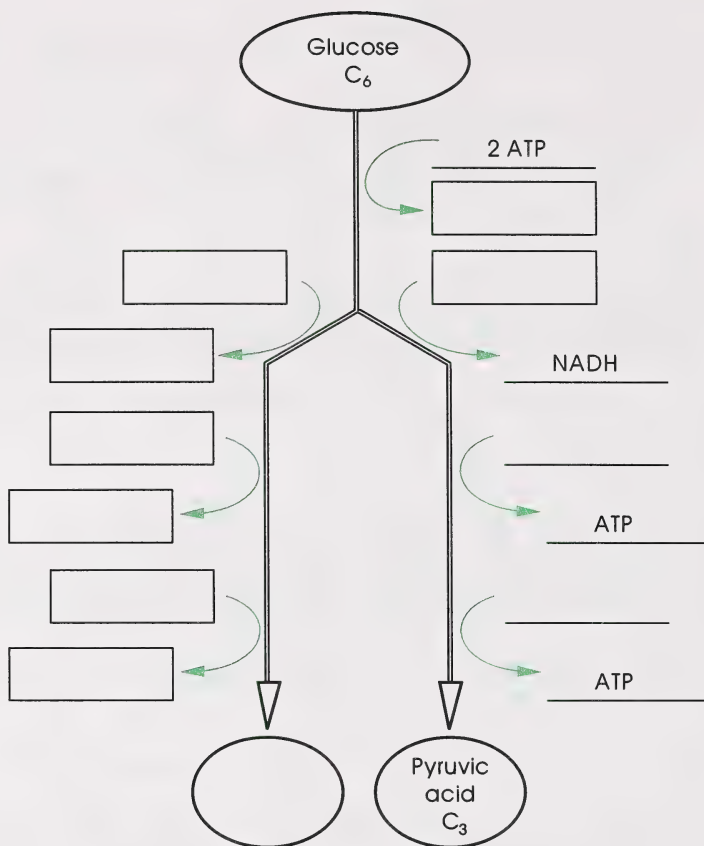
5. Of the food that you eat, which substance provides most of the energy?
6. Identify the unit molecule that composes carbohydrates.
7. Name the reaction that liberates the energy in glucose.
8. There are organelles within cells that are responsible for producing the energy for cellular activities. What are these called?
9. Sugar, specifically glucose, contains a large amount of energy. Why is energy in glucose not used directly for cellular activities?
10. Provide an explanation why ATP is used to supply energy for a reaction.
11. Draw a diagram to illustrate how ATP can add energy to another molecule. What is this process called?
12. There are three major sets of reactions that make up cellular respiration. Name these reactions and indicate where they occur.

Check your answers by turning to the Appendix, Section 2: Activity 2.



The videos *Glycolysis 1 and 2* will guide you through the reactions that split glucose into pyruvic acid. Do not pay too much attention to the molecular details; concentrate only on the general process. Answer the following questions as you watch the video.

13. If you examine the word *glycolysis*, it means the splitting of glucose. Complete the following diagram to summarize the events that occur in the cytoplasm during glycolysis.



14. Why were two ATP molecules added at the beginning of the reaction pathway?
15. NAD^+ is a strong _____ acceptor. The reduced form, NADH, will be used to generate ATP in the electron transport system in the mitochondrion.
16. Glucose is a six-carbon compound. At the completion of glycolysis, there are _____ molecules of _____ which contain _____ carbons each.
17. The energy released during glycolysis is trapped in molecules of _____ and _____. There are _____ ATP molecules produced during glycolysis resulting in a net gain to the cell of _____ ATP molecules.

Check your answers by turning to the Appendix, Section 2: Activity 2.

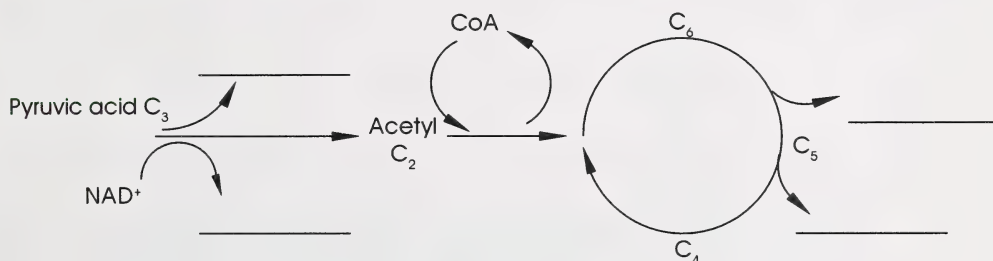


So far you have traced the breakdown of glucose into two molecules of pyruvic acid. Pyruvic acid can be broken down further to release energy. The next video *The Krebs Cycle* deals with the reactions that take place in the mitochondria. View it and then answer the next set of questions.

Science Skills

- ☐ A. Initiating
☒ B. Collecting
☒ C. Organizing
☒ D. Analysing
☒ E. Synthesizing
☐ F. Evaluating

18. Before pyruvic acid can enter the reactions in the Krebs cycle it is converted to a two-carbon molecule called _____. The carbon that is lost is in the form of _____ and the energy is trapped in _____. The acetyl now combines with _____ which delivers it to the Krebs cycle.
19. You should now be able to complete the following diagram to summarize the reactions that take place in the Krebs cycle.



Remember that each glucose molecule produces two pyruvic acid molecules.

20. Beginning with two pyruvic acid molecules, fill in the input and output of the following Krebs cycle compounds.

INPUT	OUTPUT
____ Pyruvic acid	____ CO ₂
____ ADP and P	____ ATP
____ NAD ⁺	____ NADH
____ FAD	____ FADH

Check your answers by turning to the Appendix, Section 2: Activity 2.

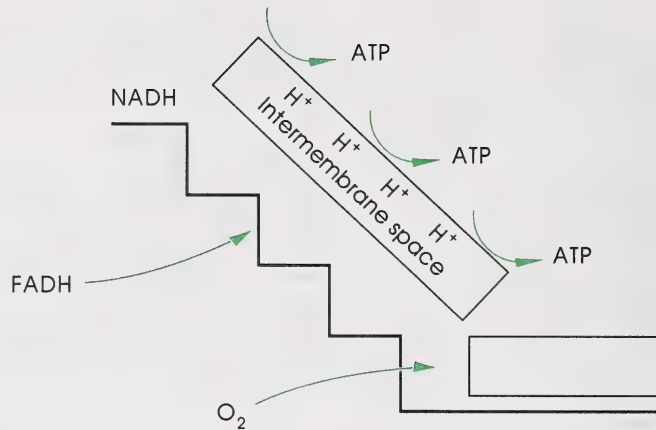


The final steps in extracting the energy from glucose is to convert the energy in the electrons that have been temporarily stored in NADH and FADH. Recall from Section 1, Activity 3 that an electron transport system will accept high energy electrons and pass them through a series of oxidation-reduction reactions. This system extracts energy from electrons to produce ATP by chemiosmosis. View the video titled *Oxidative Phosphorylation* and complete the next set of questions.

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

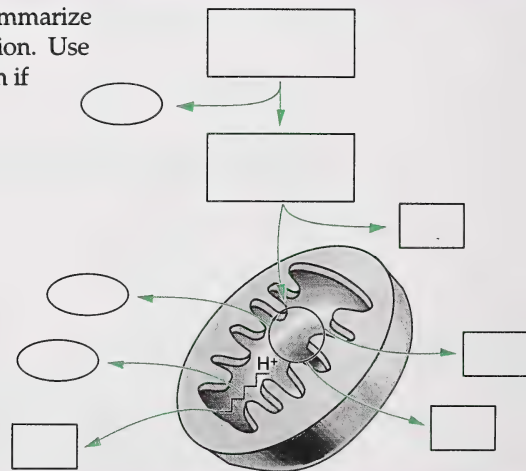
21. Trace the path that an electron would follow through this simplified electron transport system to produce ATP. Remember that these oxidation-reduction reactions release energy that pumps protons across inner mitochondrial membrane. Make sure you include the final product molecule.



22. The final electron acceptor is _____. It accepts both electrons and protons to produce _____.
23. One NADH produces _____ ATP. One FADH produces _____ ATP.

Check your answers by turning to the Appendix, Section 2: Activity 2.

24. Complete the following diagram to summarize the important ideas in cellular respiration. Use the video to help complete the diagram if you are having difficulties.



Check your answers by turning to the Appendix, Section 2: Activity 2.

Cellular respiration is the connection that liberates the energy of the sun. Whenever you eat anything remember that it's really a little packet of sunshine that will energize your cells.

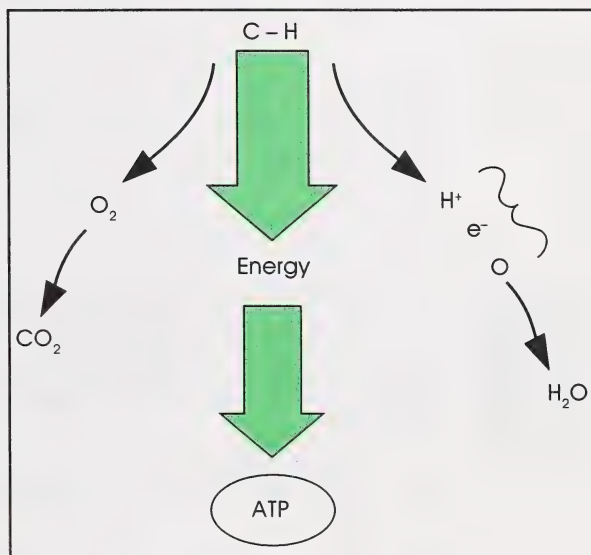
Part B

Read Oxidation and Phosphorylation on page 197 in your text and complete the following statements.

25. In respiration, high-energy compounds like glucose are oxidized to form low-energy compounds like _____ and _____.
26. During oxidation, chemical bonds between carbon and hydrogen atoms are broken. This releases _____, _____, and _____.
27. This energy is used to make _____.

Here is a very simple illustration of oxidation.

Notice the need for oxygen in this illustration. Also notice that the illustration has a left and a right side. These are two different parts of respiration. Both of these lead to low-energy compounds. The use of oxygen makes this type of respiration **aerobic**. Respiration may be either aerobic or **anaerobic**. It may surprise you, but as you will see, your need for oxygen occurs at the end of respiration, not the beginning. Much of your respiration is really anaerobic.



aerobic – a process that requires oxygen

anaerobic – a process that does not require oxygen

Read Anaerobic Respiration on page 198 in your text.

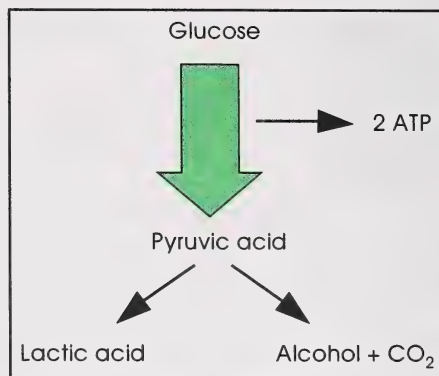
28. Even without oxygen, glucose can be partially broken down to release a small amount of energy. What product is formed this way?
29. What kind of anaerobic respiration occurs in yeast?
30. a. Besides a small amount of ATP, what other products are formed in fermentation?
- b. Which of these products may still contain energy?

glycolysis – splitting glucose into pyruvic acid

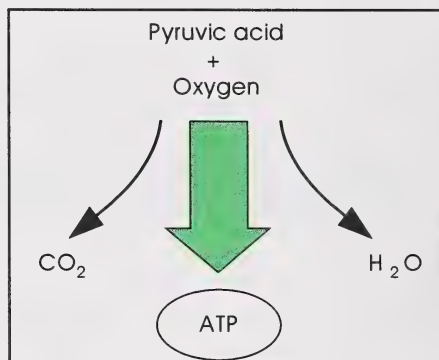
All respiration begins anaerobically. Turn to page 198 of your text and read the section entitled **Glycolysis**. Also look at Figure 7.35 on the same page.

31. What compound is the final or terminal electron acceptor in anaerobic respiration?

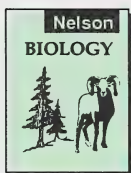
A summary of glycolysis might look like this:



So where does oxygen fit in? If no oxygen is available this is as far as respiration goes. But if oxygen is present pyruvic acid can continue to the next step. This results in the low-energy final products, CO_2 and H_2O , and releases much more energy to form ATP.



Notice this illustration has a left and a right side. You've seen something like this before. To study the right side of this reaction, read Cytochrome Enzyme System on page 200 in your text.



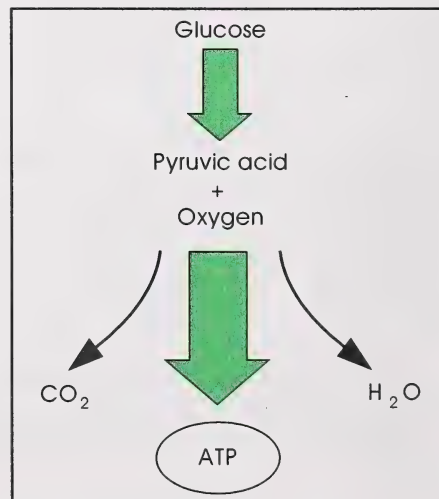
32. What are cytochromes and where are they found?

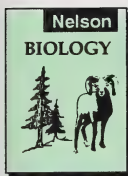
33. What happens as hydrogen and electrons move along the cytochromes?

34. a. What substance is at the end of the cytochrome system to receive hydrogen?

b. What is the final end product?

So the cytochrome system removes hydrogen atoms and electrons from glucose and with oxygen forms water. What about the carbon atoms in glucose? This is where CO_2 is formed.





coenzyme – a chemical made from vitamins that helps enzymes in reactions

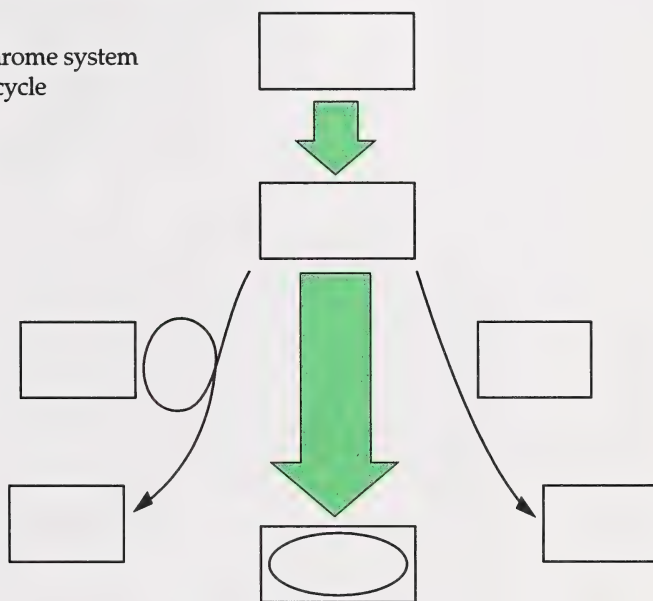
Turn to page 201 in your text and read the section entitled Krebs Cycle.

35. In the presence of oxygen, what compound will be formed from pyruvic acid?
36. Acetic acid releases a molecule of CO_2 and joins with a **coenzyme**. What new substance does this create? This new substance enters the Krebs cycle.

It is not necessary to memorize all the substances in respiration reactions. You can always look them up. What is important is that as glucose breaks and releases energy, the final result is CO_2 and H_2O . Now, you've learned that the cytochrome system forms H_2O .

37. What does the Krebs cycle form?
38. Use the following terms to complete the diagram.

- H_2O
- CO_2
- Glucose
- ATP
- Cytochrome system
- Krebs cycle



39. How much ATP forms, that is, how many molecules of ATP will be made from one molecule of glucose? Check the equation on page 200 in your text.

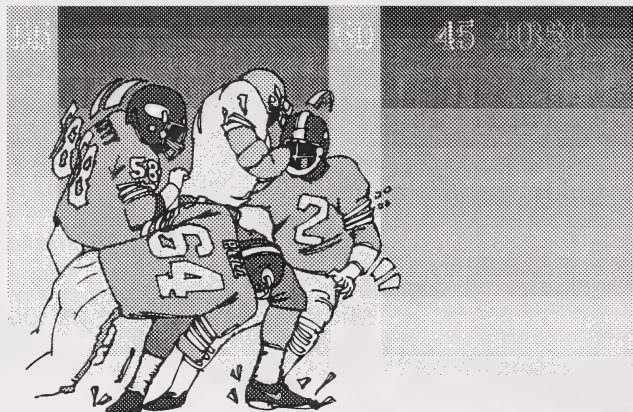
Check your answers by turning to the Appendix, Section 2: Activity 2.

This has been a challenging activity. Does all this relate to matter and energy in the biosphere? Certainly! Remember, photosynthesis captures solar energy and stores it as chemical energy. Respiration converts the chemical energy into ATP. The energy in ATP is used for the activity called life.

ACTIVITY

3

Athletes and Energy



Do you skate or ski or play an active sport? Many sports require large amounts of energy. Think about it for a moment. How much energy are you expending to study this module compared to running a kilometre as fast as you can? There's a big difference. Athletes specialize in energy expenditures. How do they do it? One way is by getting proper nutrition. Another way is through training and fitness. Good coaching also helps. But in the end it all comes down to cellular respiration, a chemical process. Increasingly, drugs and other substances are being found that increase athletic performance by altering biochemical processes. Many of these substances have negative side effects. Nearly all have been banned in regulations that forbid taking any substance that increases performance.



PHOTO SEARCH LTD.

Read the article *Bicarb Boosters* to learn of one strategy that uses a chemical to increase performance. Pay special attention to the negative side effects. Answer the questions that follow.

Bicarb Boosters

Runners get speedy with Alka-Seltzer

In the upper echelons of competitive sports, a tenth of a second can mean a world title, thousands of dollars and a long career as a consultant, and many athletes feel compelled to use drugs to better their performances. The drugs – exotic, expensive substances that make athletes stronger, faster, more aggressive and less susceptible to pain – are illegal, but the material ends of taking them are seen to justify the pharmaceutical means. It is ironic, then, that the latest substance touted to turn also-rans into Olympic champions is nothing more than sodium bicarbonate, the chemical name for baking soda and the primary ingredient in antacid pills.

There is already evidence that “buffer-boosting,” or “soda-loading” – taking large quantities of antacid – is now practised by runners intent on shaving seconds off their times, and York University professor Norman Gledhill wants antacid, such as that in Alka-Seltzer, added to the list of drugs banned in athletic competitions. Gledhill is well qualified to speak: not only is he the chairman of the Sport Medicine Council of Canada’s committee on doping in amateur sports, but he is also the first scientist to demonstrate successfully the physiological effects of sodium bicarbonate. “There were rumours that some Europeans were buffer-boosting, and lab studies indicated it should cut a runner’s time,” Gledhill says, “but there was no clear evidence that it actually worked under race conditions.”

Accordingly, Gledhill administered various doses of bicarbonate to varsity athletes before they competed in 800-metre runs. To control the experiment, the athletes were occasionally given capsules without biobcarbonate, so they never knew when they had ingested the chemical. When they had, however, the results were dramatic: the soda-loading cut an average of nearly three seconds from the racers’ normal times – more than the difference between first and last place in many competitions.

Soda-loading works by preventing muscle fatigue. In events of short duration, especially those lasting 45 to 90 seconds, lactic acid, a waste product, builds up in the muscles and the blood and prevents the muscles from contracting effectively. Antacid is normally used to soak up excess stomach acid, but if an athlete takes enough of it, the chemical enters his bloodstream and neutralizes the lactic acid, which means his muscles do not tire as quickly during a competition.

The secret to successful buffer-boosting is timing precise doses. Too little of the bicarbonate has no effect, and too large a dose can cause vomiting or diarrhea. After several trials, Gledhill found that the most effective regimen was for the athlete to take 14 capsules – each containing 1.5 grams of bicarbonate – over the two hours prior to a race. The amount equals that contained in 12 Alka-Seltzer tablets.

Gledhill believes the potential

for performance improvement is even greater than that demonstrated in the York University tests. “Even though the athletes ran faster, they didn’t feel they had performed well,” says Gledhill, “because they still had energy after the race. Runners are taught to use up everything they have by the end of the race, and these athletes were crossing the line with energy to spare. If they trained with the bicarbonate, they’d learn to use all the available energy and cut their times even further.”

Although all of the York experiments were on athletes running the 800-metre event, soda-loading could be useful in events lasting up to half an hour, including most of the longer running events, swimming and wrestling. The half-hour limit is necessary because 50 percent of the buffer-boosted athletes are afflicted with violent diarrhea about 60 minutes after the last dose. The bowel distress appears to be the only side effect of the treatment.

Far from advocating the use of bicarbonate to train athletes, however, Gledhill wants to ban it. “It’s already against the rules, since regulations against doping forbid taking any exogenous substance to improve performance. But up to now, officials haven’t been testing for it.” It is time, he says, to start. “I’m convinced that some athletes are already soda-loading. It’s cheating, and I hope we will soon have it under control.”¹

–James Carlisle

Although taking baking soda can shave seconds off a runner’s times, York professor Norman Gledhill is campaigning to ban the substance from athletic competitions.

¹ Reprinted with permission of *Equinox Magazine*, Sept./Oct. 1984. Telemedia Communications Inc.

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

1. What are two common substances that contain sodium bicarbonate?
2. What is lactic acid and why does it accumulate in muscles and the blood stream?
3. If lactic acid builds up during exercise, what happens to the athlete?
4. How does soda-loading, as described in the article, work to improve performance?
5. Why were the runners in the tests given capsules with no bicarbonate in them?
6. List the advantages and disadvantages of using sodium bicarbonates as a performance-enhancing drug.
7. Do you feel there should be regulations regarding the use of sodium bicarbonate by athletes? Explain why.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Recall that anaerobic respiration and lactic acid production are described in your text on pages 198 to 199. Review these pages if necessary.

8. What causes the buildup of lactic acid?
9. What happens to a person who does not eliminate the lactic acid waste?
10. How does a person normally eliminate lactic acid?

Check your answers by turning to the Appendix, Section 2: Activity 3.

ACTIVITY

4

Pollutants and Respiration

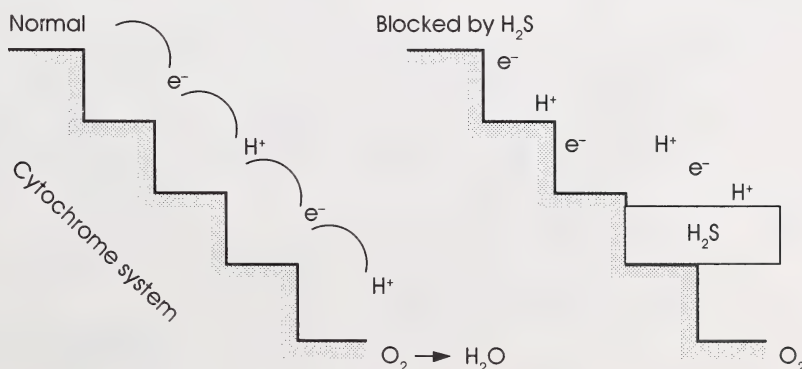
Have you visited a hot springs area such as in Banff or spent any time in a northern swamp in summer? What do hot springs, swamps, sour gas wells, and even volcanoes have in common? They all smell like rotten eggs; there is a common gas released by these areas.



ALBERTA PUBLIC AFFAIRS BUREAU

The gas is hydrogen sulphide (H_2S) and it is very toxic. Don't panic, toxicity depends on concentration and often the concentration may be quite low and still create a bad odour. At low concentrations such as one part per million (ppm), which is the level released by the Banff Hot Springs, you detect a slight odour. The problems start at 20 ppm when your eyes begin to burn, you feel nauseated, and you begin to lose your sense of smell. When levels reach 200 ppm healthy individuals will experience more severe problems. Fatality will occur when gas levels reach 600 ppm. Alberta has set a maximum desirable level of 0.17 ppm. This is the level that should not be exceeded in a populated area.

Biologically, hydrogen sulphide causes harm by blocking the electron transport or cytochrome system.



When the cytochrome system is blocked, several negative effects occur.

1. Using your knowledge of respiration, predict one effect of blocking this system.

pH – level of acidity
Normal blood pH is about 7.44.

Another effect of blocking the cytochrome system is the immediate increase in hydrogen ions (H^+) and electrons (e^-) in the body. This can lower normal body **pH**. Many chemical reactions in the body require a stable pH. Any change in pH can have immediate and serious consequences. Poisons such as cyanide work this way. So hydrogen sulphide is to be treated with caution.



AOSTRA

How is hydrogen sulphide normally handled? Hydrogen sulphide is often encountered when drilling for oil and natural gas in Alberta. Normally the gas is controlled by combusting it to form sulphur dioxide and solid sulphur. In small amounts the sulphur dioxide may be released to the atmosphere. The solid sulphur can be sold as fertilizer. You may have seen railway cars loaded with sulphur travelling through Alberta.

However, sometimes something can go wrong. If large amounts of gas are suddenly encountered and burst from the well, a blow-out occurs. The situation becomes even more serious if the escaping gas ignites. This is one of the risks in oil and gas exploration, and it occasionally happens in Alberta.

A blow-out occurred at about 2:15 a.m., on October 17, 1982 at the Amoco Dome sour gas well located 18 km east of Lodgepole, Alberta. The blow-out spewed about two-million cubic metres of gas into the atmosphere each day for sixty-eight days.



PHOTO SEARCH LTD.

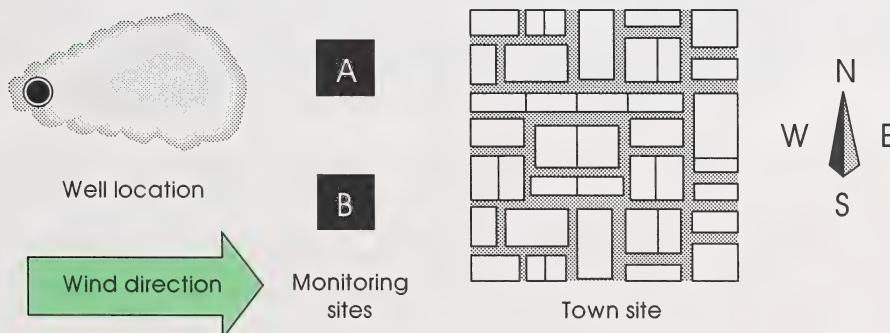
Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

2. What would be your first clue that there was a hydrogen sulphide leak?

The following exercise is to help you understand the effects on the population of a town if there were to be a sour gas well blow-out. This fictitious well has blown out just 25 km west of the town in which you are living. The efforts to cap the blow-out have failed consistently causing millions of cubic metres of hydrogen sulphide to be released each day. The wind is currently blowing due east toward your town. The environmental control board for the town has hired a monitoring firm to test the levels of hydrogen sulphide west of the town. The board has decided that if the levels reach 25 ppm the town will have to be evacuated.

Map of the Area



The following data are readings from the two monitoring stations.

TIME AFTER BLOW- OUT (DAYS)	H ₂ S READINGS	
	Site A (ppm)	Site B (ppm)
1	5	3
2	7	5
3	20	7
4	23	8
5	15	22
6	17	20
7	30	28

- Produce a graph of the data from the two monitoring stations. The line graph should include the data from both Site A and Site B.
- According to the data provided, on what day should your town be evacuated due to the blow-out?
- Why do the levels of hydrogen sulphide increase as the days go on?
- Why might the levels of gas recorded at Site A jump so dramatically on the third day?
- Why might the levels of gas recorded on the fifth day decrease at Site A but at the same time increase at Site B?
- On the ninth day the gas company was able to cap the blown well. You are chosen by the town to sit on an advisory board to formulate a policy related to the operation of the well. List the points you would want to include in the policy.

The problem of hydrogen sulphide is of major concern to any town situated close to an operating sour gas well. Workers on the well site must also be extremely cautious as they are in constant danger of breathing in very high concentrations. It is sad to note that there have been deaths of well workers due to the effects of this inhibitor of cellular respiration.

Check your answers by turning to the Appendix, Section 2: Activity 4.

Methane: A Gas from Anaerobic Respiration

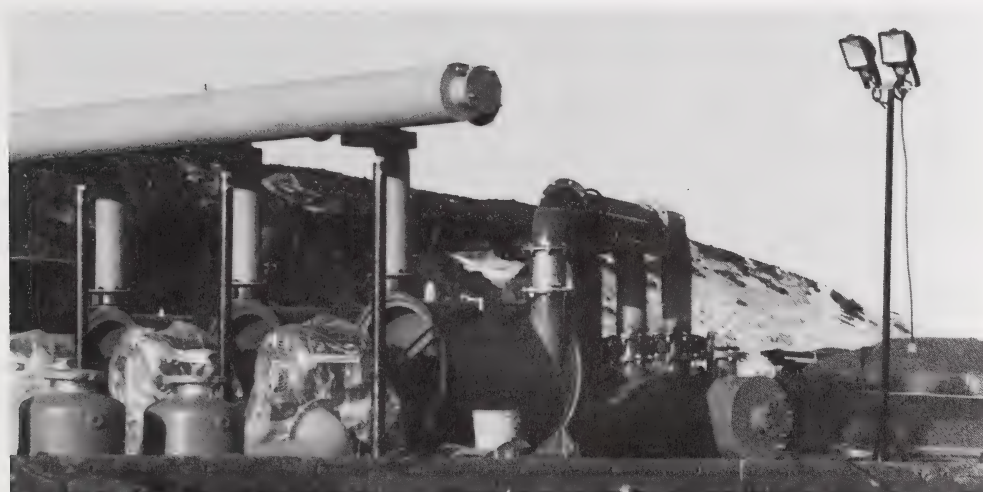
Another smelly gas found around swamps is methane (CH₄). This gas is produced by bacteria living on organic material under anaerobic conditions, that is, without oxygen. One place this occurs is in garbage dumps where organic material is buried in a landfill.



Clover Bar Landfill

COURTESY OF EDMONTON POWER

Methane, or natural gas, is an important fuel. Could there be an opportunity here for a science, technology, and society (STS) connection?



Clover Bar Methane Extraction Technology

COURTESY OF EDMONTON POWER

The City of Edmonton is using the gas produced by decomposing garbage to supply part of the fuel needed for a gas-fired electrical generating plant.

To find out more about this technological solution, read the following article and then answer the question.

Gas from rotting garbage brings light to city homes

ADRIENNE TANNER
Journal Staff Writer

Edmonton

Rotting banana peels and other forms of decaying household garbage are turning on the lights in 6,800 Edmonton homes.

Methane gas produced by rotting garbage in the Clover Bar Landfill is being processed and piped to the nearby Clover Bar power station to help fuel the generators.

The process begins at the bottom of about 80 shallow wells spread throughout the landfill, which initially taps the methane gas. A vacuum system in a nearby processing plant pumps the methane to the plant, where it is filtered, compressed and sent off to the generating power station.

When it reaches the station, it's mixed with natural gas and becomes part of the fuel that provides the energy.

"What happens is that once it's mixed, the mixture is set on fire," said Richard Finnigan, a spokesman for Edmonton Power. "Then the heat from the fire produces steam and the steam drives a turbine, the turbine drives the generator and then you have electricity and that's what lights people's homes."

Tapping into the landfill gas supply was the brain-child of businessman Dick Collens, president of Environmental Technologies Inc., a Calgary company which specializes in landfill gas recovery.

The project is the first of its kind in Alberta and only the third in Canada, Collens said.

Realizing the power station would be a steady customer for the methane, Collens spent \$2.5

"METHANE HURTS THE OZONE AND CAN ACTUALLY DAMAGE HOUSES IF IT SEEPS INTO BASEMENT STRUCTURES."

— DICK COLLENS



million to build the gas-processing plant at the landfill site on the eastern edge of Edmonton.

The city, pleased at the prospect of adding a minimum of \$25,000 in gas royalties to its coffers each year, agreed to buy the methane for about the same price as pipeline natural gas.

Once the project is running at full steam, the city will net \$75,000 a year in royalties. At full capacity, about 200,000 cubic metres of gas will be drawn from the landfill each day — enough to supply power to 13,000 homes.

The project's expected lifespan is 20 years.

Speaking above the noise of seagulls squawking overhead, Mayor Jan Reimer praised the project as a "very good day for the citizens of Edmonton" at opening ceremonies for the processing plant Tuesday afternoon.

Edmonton will benefit financially from the project, she said.

But the real winner, said

Reimer, is the environment.

Methane is a harmful greenhouse gas and a major contributor to global warming, Reimer said.

Burning methane to create power produces carbon dioxide and although it, too, is a greenhouse gas it is 27 times less harmful than methane, Collens said.

"Methane hurts the ozone and can actually damage houses if it seeps into basement structures," he said.

All landfills generate methane, which along with carbon dioxide is produced when garbage rots underground.

Some burn off the harmful methane to minimize the environmental impact.

But other landfills take no flaring measures and simply allow the methane to gradually seep into the atmosphere.

Recovering methane from landfills is tricky work, said Collens, whose staff consists mainly of oil and gas engineers.

"You have to know how to handle landfill gas."

Careful adjustments must be made to each of the shallow wells at the Clover Bar site every day, said Doug Heath, environmental project engineer with Edmonton Power.

"One thing they have to be careful of is that they don't suck too hard," Heath said.

Because if, by mistake, oxygen is injected into the buried garbage the decomposing process will yield water and carbon dioxide instead of methane, he said.

Even at peak production levels methane generated by the landfill will make up only three percent of the power plant's supply.¹

¹ The Edmonton Journal for the article, taken from pp. A1 & A2, April 22, 1992 issue. Reprinted with permission of The Edmonton Journal.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

9. Identify three advantages and if possible three disadvantages of landfill gas extraction.



COURTESY OF D. MERRILLS

Anaerobic bacteria can also be used to break down domestic sewage. Again, methane gas is produced naturally. For many years the City of Edmonton has recovered methane from anaerobic digestion during sewage treatment. The methane produced in large digesters is used to heat the buildings at the Gold Bar Sewage Treatment Plant.

After treatment the sewage, now called sludge, can be used as agricultural fertilizer.

10. a. Describe the advantages these two projects will have as the city grows larger.
- b. Could either of these projects work on a small scale such as in a single home or in a small community? Describe the variables that would have to be considered.

Science Skills

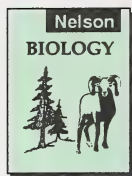
- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

Check your answers by turning to the Appendix, Section 2: Activity 4.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help



The process of cellular respiration can be quite confusing. To understand it better, review the pertinent areas in your text found between pages 197 and 202. You may also want to review the videos as well to help you in completing this Extra Help.

1. The high-energy compound _____ is converted into the low-energy compounds _____ and _____.
2.
 - a. State the first step in cellular respiration.
 - b. State the final electron acceptor in glycolysis.
 - c. State the two energy-containing products of glycolysis.
 - d. Why does lactic acid accumulate in cells during strenuous activity?
3.
 - a. The terminal electron acceptor in cellular respiration is _____, which combines with hydrogen to produce _____. Without the constant supply of oxygen, aerobic respiration would _____.
 - b. There are five main products of the Krebs cycle. List the three energy-containing compounds produced. List the two compounds that are released during cellular respiration.
4. Answer question 27 on page 202 of your text.
5. The toxic gas hydrogen sulphide is a constant threat to any organism that might inhale it. The most dangerous source of this gas in Alberta is sour gas wells. How does hydrogen sulphide prevent the production of cellular energy?

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

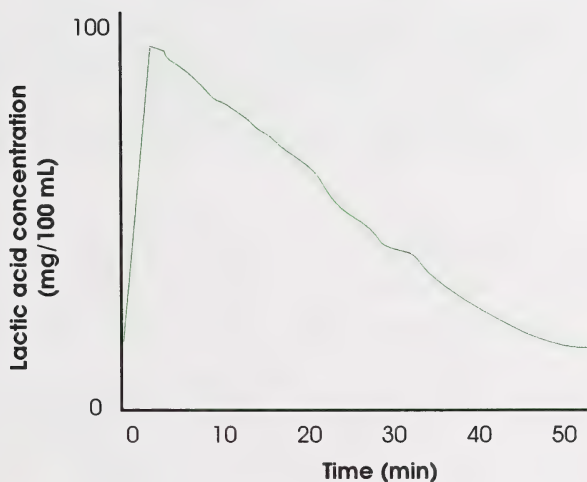
Do one or more of the following.

1. A physical education student was given the task of organizing the track meet for the local junior high school. The student began to create an event schedule. It seemed logical to the student to put all of the 200 m sprint heats and the final in the first hour of the day so that these athletes could go on to other events later on in the day. The student knew that the winners of the heats would need to catch their breath before the next race and so included a rest break before the final race. The schedule devised by the student was as follows.

Heat 1 – 9:00 a.m. Heat 3 – 9:20 a.m.
Heat 2 – 9:10 a.m. Final – 9:40 a.m.

The schedule was then turned in to the teacher in charge for approval. The teacher commented on the fact that it was well organized and that giving the runners time to catch their breath was important. The student had, however, forgotten to include a recuperation period from lactic acid buildup. If runners have not fully recuperated from lactic acid buildup they will be at a disadvantage during the next race. The student was given the following graph and instructed to rework the schedule.

BLOOD LACTIC ACID CONCENTRATION AFTER STRENUOUS COMPETITION



Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

- a. During the 200 m sprint, which lasts about 30 s, is the runner working aerobically or anaerobically? Why?
- b. At what time after the race would starting another competition be least advisable? Why?
- c. At what time after the race should the runner be able to compete with maximum efficiency? Why?
- d. What would be the earliest appropriate time for the final race if Heat 3 is at 9:20 a.m.?

Check your answers by turning to the Appendix, Section 2: Enrichment.

2. Imagine you have to make the decision as to whether or not to collect the gas produced by decomposing garbage. Identify three reasons why it is more favourable to collect the gas and explain why each of these is a factor in your decision-making process.

3. In developing areas around the world, biomass is used to provide the energy for cooking, electricity, or conversion to fuels such as alcohol or methane gas.

ENERGY PROVIDED BY BIOMASS IN DEVELOPING COUNTRIES	
Country	Percentage of energy from biomass
Nepal	98
Ethiopia	95
Niger	86
Bangladesh	71
India	53
Bolivia	44
Brazil	34
China	29
Mexico	9
Libya	5

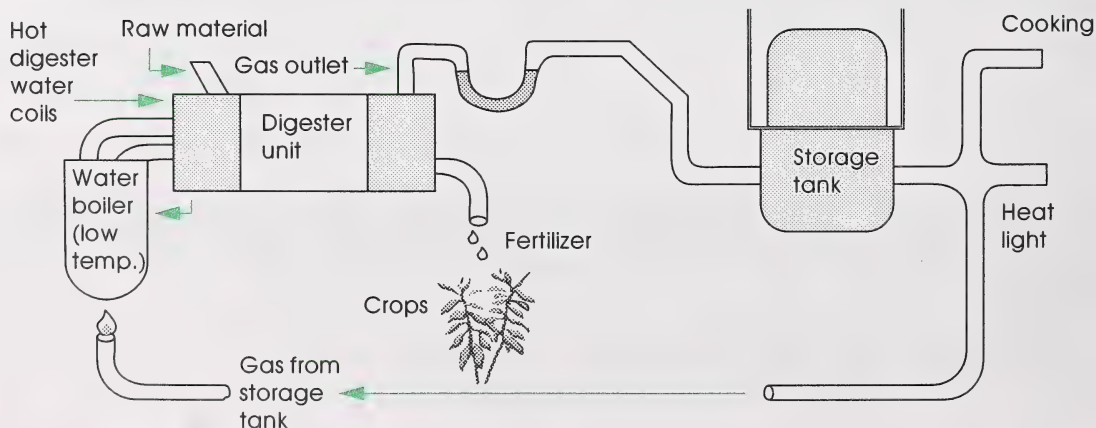
As you can see from the table, a tremendous amount of biomass is being used just for energy. Most of this is in the form of wood. The majority of trees cut down on the planet are not used as wood products but are in fact still used for fuel.

How does the removal of trees relate to the greenhouse effect?

4. Animal dung is used as a source of biomass energy in many developing parts of the world. However, using this for fuel wastes precious material that could be used as fertilizer. The following diagram illustrates a process where anaerobic respiration of organic material is used to produce methane gas.

Methane digester

In the digester unit, anaerobic bacteria convert animal waste into methane gas. This gas is then used as a source of fuel. The sludge from this process serves as a fertilizer. In many less-developed countries, this type of digester has the advantages of providing a source of energy, providing a supply of fertilizer, and managing animal wastes, which helps to reduce disease.



As you can see, it is similar to the collection of gas from landfills that you examined earlier.

- a. In what way is using the dung or organic material in this manner beneficial to agriculture in these regions?

China has 500 000 small methane digesters in homes and on farms. These could be placed on Canadian farms and used to provide gas to provide energy, but other than a few individual experimental projects, it is not done.

- b. Identify the major reason as to why the use of methane digesters is not a common practice in Canada. Explain.

Check your answers by turning to the Appendix, Section 2: Enrichment.

5. For more information on the City of Edmonton methane recovery projects, write to either of the following:

Mr. Doug Heaton
Environmental Project Engineer
Edmonton Power
10065 Jasper Avenue
Edmonton, Alberta
T5J 3B1

G.G. Emanuel
Director, Wastewater Treatment
13th Floor, Century Place
9803-102A Avenue
Edmonton, Alberta
T5J 3A3

Conclusion

In this section you learned how energy, captured by plants and stored in carbohydrates, is transferred to ATP. The production of ATP is a vital link between solar energy and cellular activities. You also studied the effects of toxins like hydrogen sulphide on ATP production and the possible conflict between industry and human life.

Another aspect of cellular respiration was explored within athletic training and the use of related chemicals. Finally you studied an STS connection to respiration in the anaerobic production and recovery of methane gas.

50

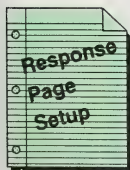
Section 2 Assignment: ATP: The Energy in You

Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

Biology 20 – Module 5 Section 2 Assignment Page # Name and ID#

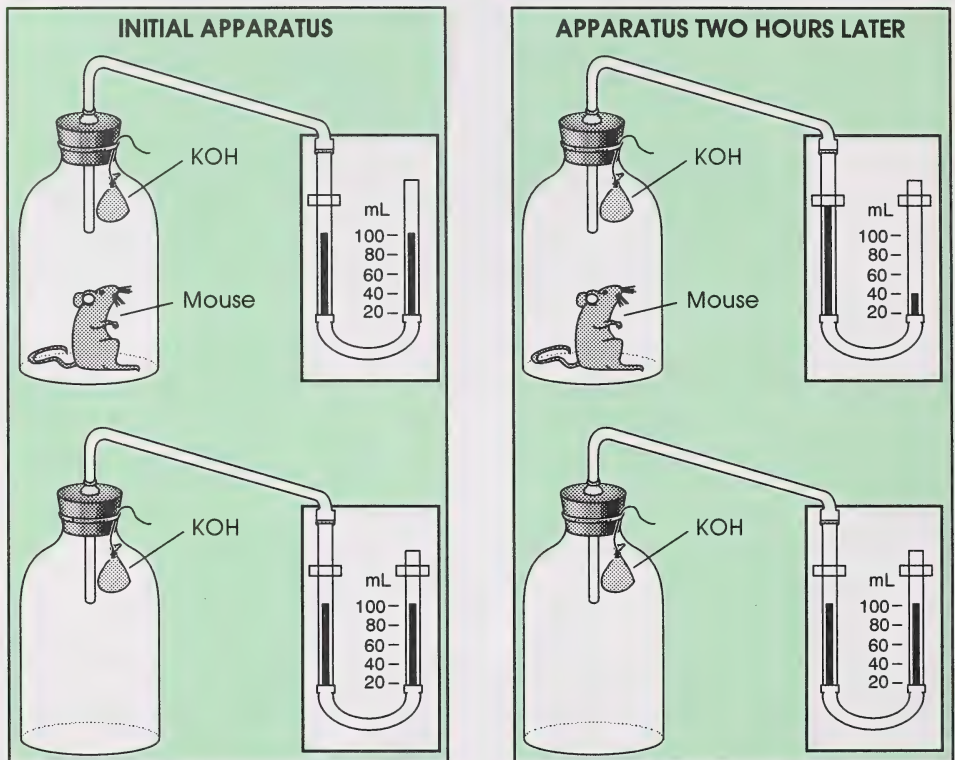
Be sure to write legibly. Leave a wide left margin and number all of your pages.



1. Cyanide is a deadly chemical that blocks the electron transport system. Explain two ways why exposure to cyanide would cause death almost immediately. (4 marks)
2. Imagine you set up the apparatus shown in the following diagram to determine the O_2 consumption of a mouse. After a two-hour period the following could be observed. (6 marks)

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

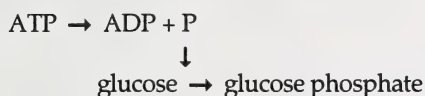


- a. Calculate the metabolic rate in $mL O_2/g/h$ if the mass of the mouse is 20 g.
 - b. Explain why you set up the flask that did not contain a mouse.
 - c. Why must the packet of KOH be present?
3. a. The following reaction takes place in your muscle cells. Is this reaction aerobic or anaerobic? Explain your answer. (4 marks)

glucose $\rightarrow$ pyruvic acid $\rightarrow$ lactic acid

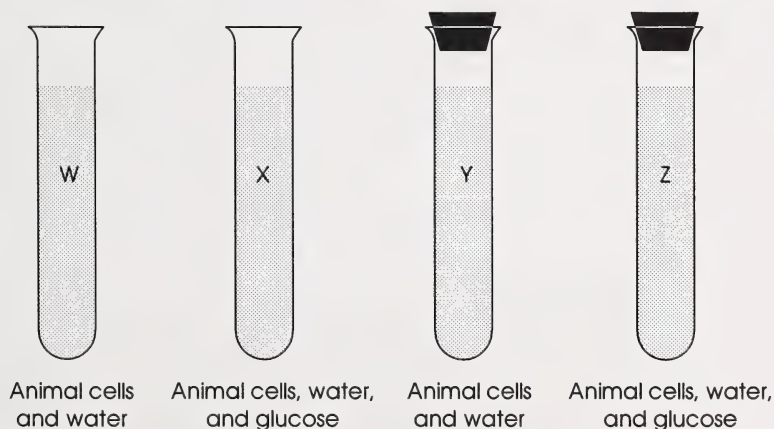
 - b. Explain how athletic training delays this reaction in an individual?

4. Sketch a diagram of a cell that illustrates where glycolysis, the Krebs cycle, and the electron transport reactions occur. Your diagram should consist of a cell membrane, cytoplasm, and an expanded mitochondrion. (6 marks)
5. Oxygen is a key compound in aerobic cellular respiration. Identify oxygen's role and explain its importance. (2 marks)
6. a. Oxidation-reduction reactions are critical to the respiration process. On a simple diagram compare the direction of movement of electrons in oxidation and reduction reactions. (4 marks)
- b. NAD^+ is a strong electron acceptor. What other particles does it attract in cellular respiration?
7. The following process occurs at the beginning of glycolysis. (4 marks)



- a. For what purpose does this reaction take place?
- b. What is the name of this reaction?

Examine the following diagram and answer the question that follows. A student sets up four test tubes containing an equal amount of live animal cells.

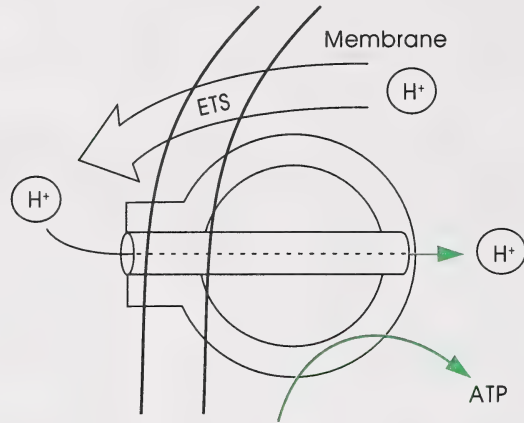


8. After two hours, which test tube would contain the maximum amount of ATP? Explain your answer. (4 marks)

Science Skills

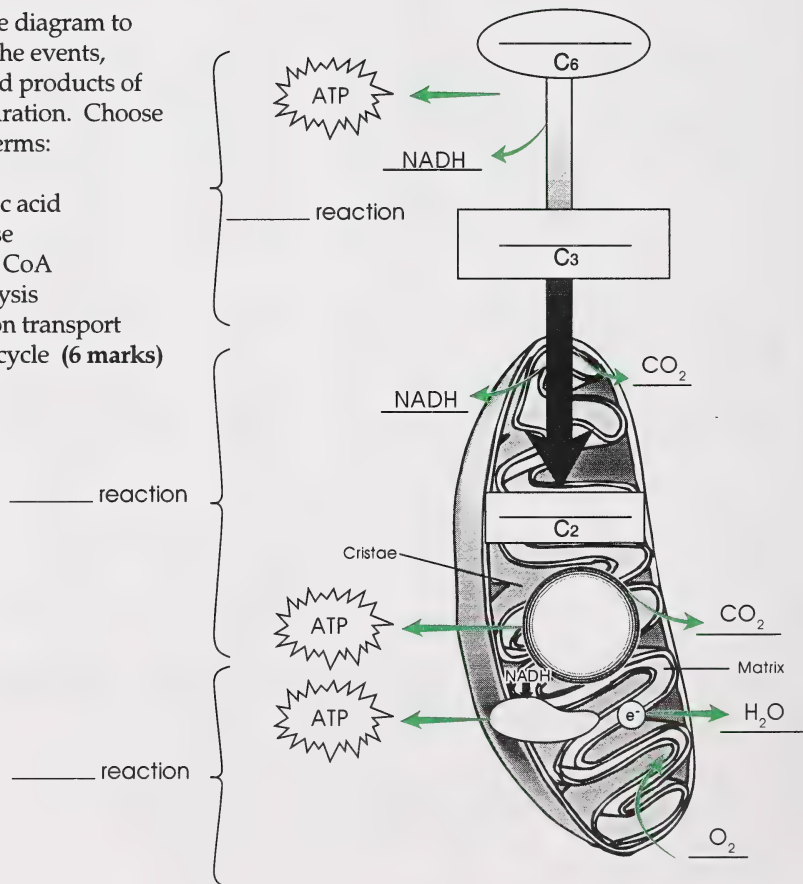
- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

9. The following diagram illustrates ATP production in mitochondria. Name this process and explain how it takes place. (4 marks)



10. Complete the diagram to summarize the events, reactants, and products of cellular respiration. Choose from these terms:

- Pyruvic acid
- Glucose
- Acetyl CoA
- Glycolysis
- Electron transport
- Krebs cycle (6 marks)



Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

11. Construct a table to compare aerobic and anaerobic respiration in terms of reactants, products, and ATP production. (6 marks)

MODULE SUMMARY

This is the end of Module 5. You've come a long way. You began with the study of matter and energy in the biosphere, in ecosystems, populations, and finally in cells. In Module 5 the key processes of photosynthesis and respiration explained how energy is captured on Earth and made available for living processes. Science, technology, and society use this knowledge in various ways that affect the world in which you live. Throughout your studies keep in mind that as a living organism you are a part of life in the biosphere.

You should now have a deeper understanding and appreciation for local ecosystems as well as ecosystems in other parts of the world. They all function by the same principles involving the flow of matter and energy.

To ensure that all of your work has been completed in a satisfactory manner, check off the items in the following list:

- ☐ Section 1 Assignment has been completed.
- ☐ Section 2 Assignment has been completed.
- ☐ Your responses are organized and neat, with room for teacher comments.
- ☐ All your response pages are numbered consecutively and identified with this heading.

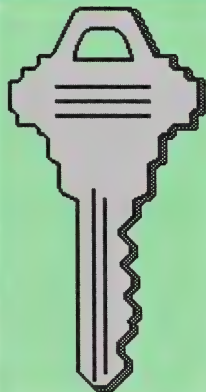
Biology 20 – Module 5

Section # Assignment

Page #

Name and ID #

Appendix



Glossary

Activities

Extra Help

Enrichment

Glossary

aerobic: a process that requires oxygen

anaerobic: a process that does not require oxygen

ATP: adenosine triphosphate

chemiosmosis: the flow of protons across a membrane

chromatography: a method that separates chemicals in solution and collects them on different areas on absorbent paper

coenzyme: a chemical made of vitamins that helps enzymes in reactions

concentration gradient: different concentrations of a substance across a barrier

glycolysis: splitting of glucose (C_6) into pyruvic acid (C_3)

pH: level of acidity
Normal blood pH is about 7.44.

Suggested Answers

Section 1: Activity 1

1. The chemical that gives leaves their green colour is chlorophyll.
2. Chlorophyll is able to allow the eventual transformation of sunlight, water, and carbon dioxide into sugar and starch in the cell.
3. The three layers that are stacked together to form a chloroplast are proteins, fats, and chlorophyll.
4. The food-making process that occurs in all plants is called photosynthesis.
5. The top half of the leaf appears a lighter yellow colour, whereas the bottom half appears a darker colour. The dark colour is due to iodine reacting with a large amount of starch present in the leaf. The top half of the leaf was covered over so that light could not shine on it; therefore, starch was not produced. If very little starch is present, the colour will be lighter.
6. The bottom half of the leaf produced starch because light was captured by the chlorophyll which then allowed photosynthesis to take place.
7. Chemical equation: $6\text{CO}_2 + 12\text{H}_2\text{O} + \text{Energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$
Word equation: carbon dioxide + water + sunlight $\rightarrow$ glucose + oxygen + water
8. The object would appear orange.
9. Engelmann was a very clever scientist to be able to come up with such a simple yet effective experiment. The purpose behind his experiment was to determine which wavelength (colour) of light produced the highest amount of oxygen when *Spirogyra* was carrying out photosynthesis.

10. It is very important to include variables when analysing an experiment.
 - manipulated variable: the wavelength of light shone onto the plate of algae
 - responding variable: the location of bacterial growth on the plate
11. The oxygen-seeking bacteria are essential to determine where the highest amount of photosynthesis is occurring.
12. Engelmann's experiment proved that blue and red light are able to cause photosynthesis to occur at a higher rate than any other colour in the spectrum. Photosynthesis releases oxygen and this is proven by the fact that the oxygen-seeking bacteria had the highest density around these two colours. The lowest density of bacteria occurred near the green and yellow bands of light. This would be due to plants not absorbing green light but rather reflecting off the chlorophyll, giving them a green appearance.
13. The colour bands produced from the experiment could take a number of different forms due to a variety of variables. The general look of the filter paper should be as shown in Figure 5.1.
14. You should have obtained three different coloured bands.
15. Chemicals will move faster up the paper due to their solubility with the water solvent. Blue must have a higher solubility than yellow, with red having the lowest solubility.
16. The chromatography paper diagram you drew should look like the diagram in Figure 5.2.
17. The two green bands on the bottom of the chromatography paper are both chlorophyll. They are separated because there are actually two types of chlorophyll. Chlorophyll *a* would be found lower on the paper and chlorophyll *b* would be found directly above it.
18. The colours of light that are most effectively absorbed are blue-violet and red.
19. Other pigments would be necessary to absorb the other colours of the spectrum that chlorophyll *a* and chlorophyll *b* are unable to absorb. These pigments are then able to aid in photosynthesis.
20. The decreasing daylight as fall approaches causes the production of chlorophyll to cease. Chlorophyll present in the leaf is degraded and the remaining pigments are then able to be seen. Some species actually produce more of these pigments if the sugar content in the leaves increases. This will occur when the autumn days are bright and cool.

FIGURE 5.1

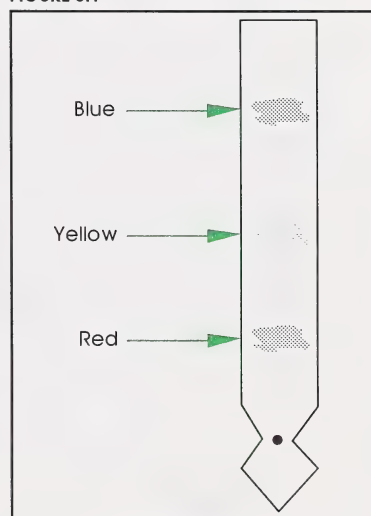
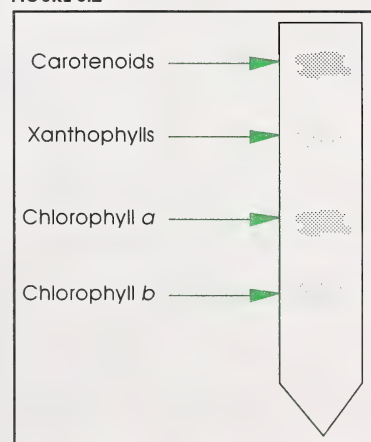
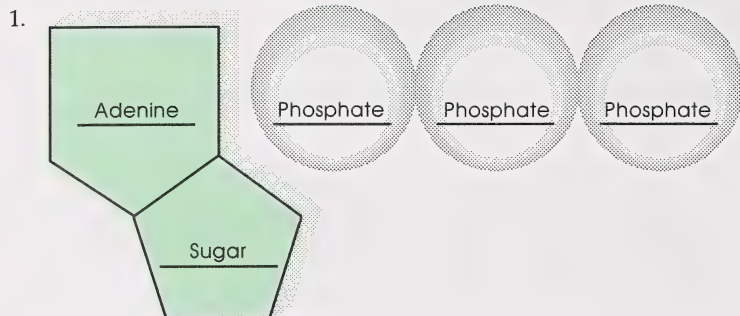


FIGURE 5.2



Section 1: Activity 2

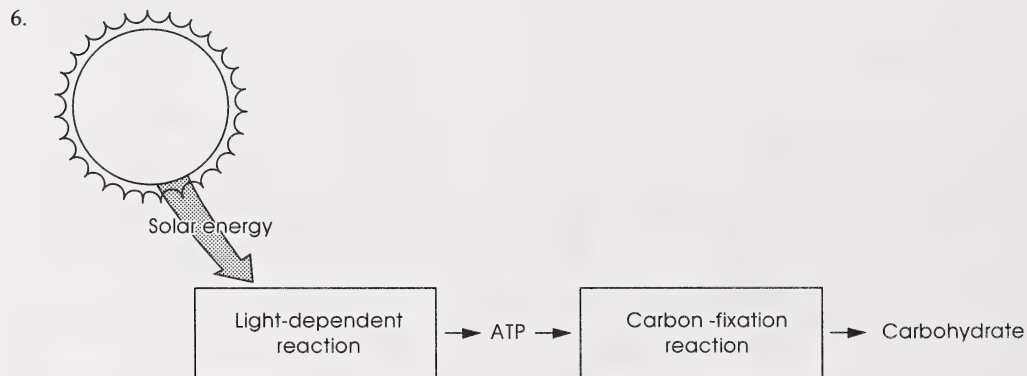


2. A-P-P~P

3. Both silver and gold are sought-after valuables. If you were to choose between the two, gold would be preferred because of its higher value. Of course silver still has a value of its own. ADP and ATP are much the same in their relationship. Both are valuable but ATP would be preferred because it is able to provide more energy than ADP.

4. To regenerate ATP from ADP and phosphate, energy would be required to reform the high energy bond.

5. The two general reactions are the light-dependent reaction and the carbon-fixation reaction.



7. The clusters of light-absorbing pigments are called photosystems.

8. Electrons are pushed to a higher energy level.

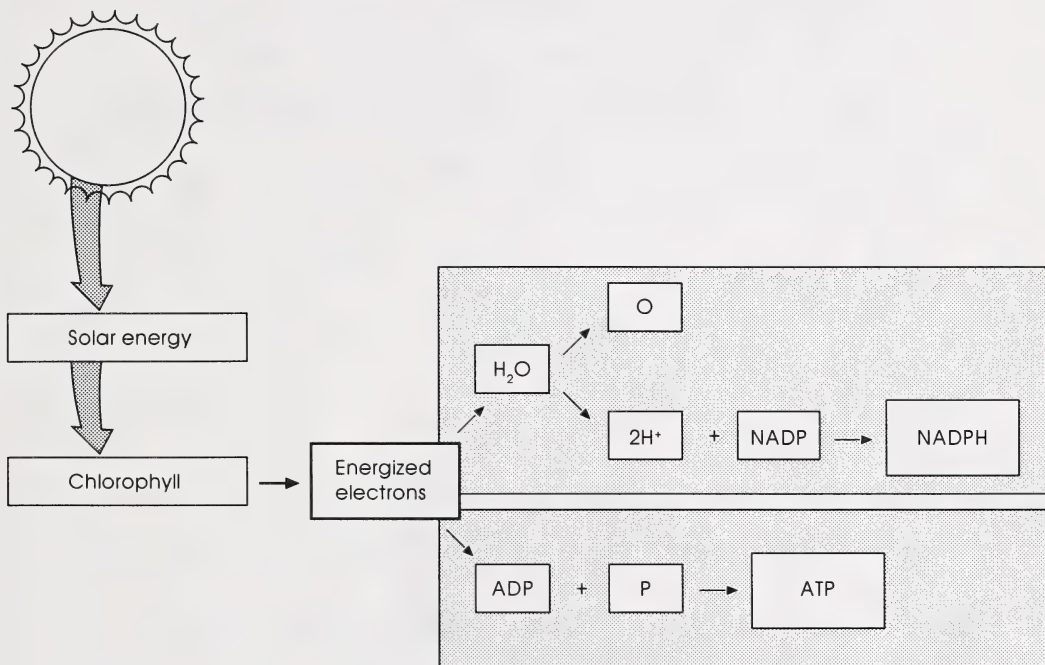
9. When the electrons return to a lower energy level, the energy is released and is used to form ATP.

10. Water is split into protons (hydrogen atoms), electrons, and oxygen atoms.

11. Oxygen is released to the atmosphere.

12. The hydrogen atoms are attached to NAD to make NADH. Incidentally, NADPH is known as nicotine aden nicotinamide adenine dinucleotide phosphate.

13.



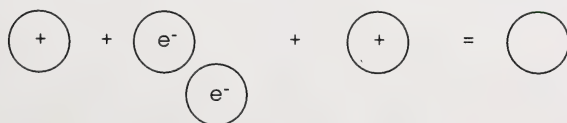
14. Formation



Breakdown

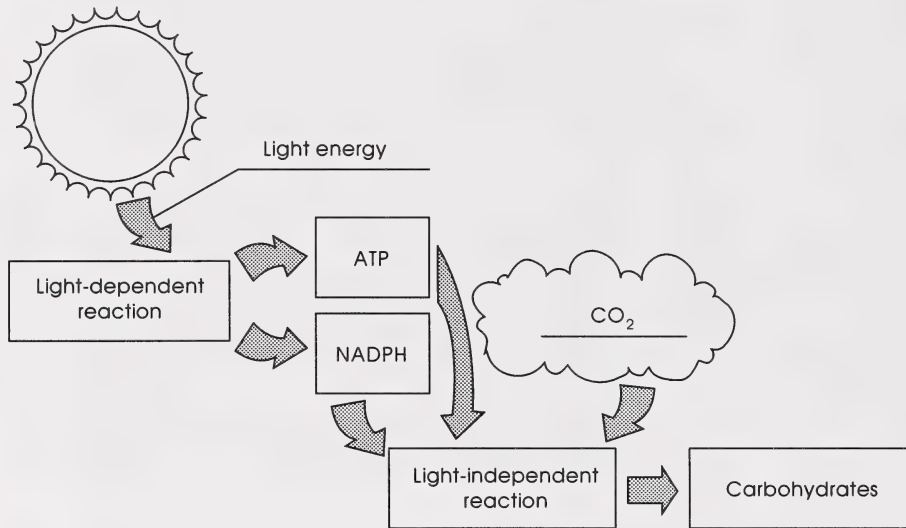


15. Two electrons are needed.



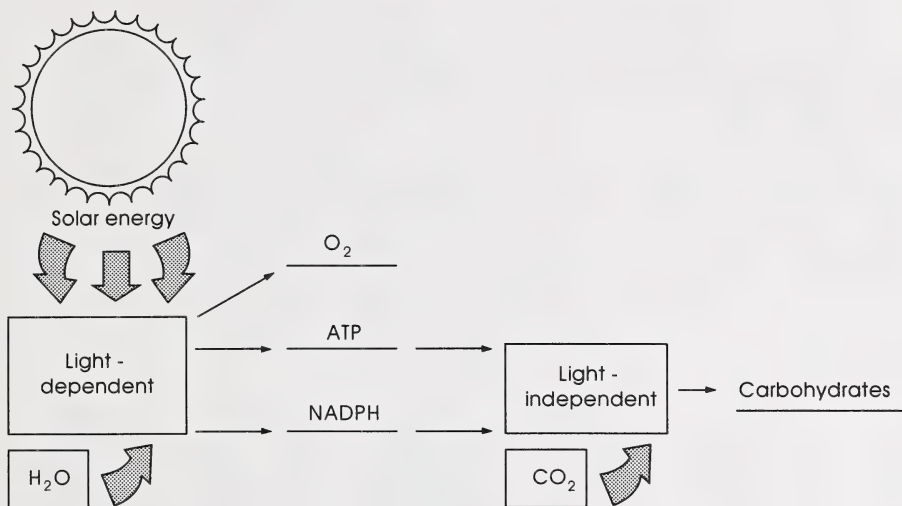
16. Thylakoid membranes are around the thylakoid discs in chloroplasts.
17. ATP and NADPH are the two energy-containing compounds.
18. Melvin Calvin and Andrew Benson co-discovered the light-independent reactions.
19. The reaction takes place in the stroma or the space around the grana or thylakoid membranes.
20. The initial carbon comes from carbon dioxide in the atmosphere.

21.



22. The four key intermediate compounds are
 - RuBP, ribulose biphosphate
 - C_6 , an unstable six-carbon sugar
 - PGA, phosphoglyceric acid
 - PGAL, phosphogly ceraldehyde
23. PGAL is also a product of the Calvin-Benson cycle.
24. PGAL may
 - provide energy for the carbon fixation reaction
 - be converted to glucose and stored
 - be used to form RuBP
25. Glucose, sucrose, and starch can be made from glucose phosphate. Cellulose can also be made.

26.



27. Following are answers for the Laboratory Application Questions 1 to 6 on page 196 of your text:

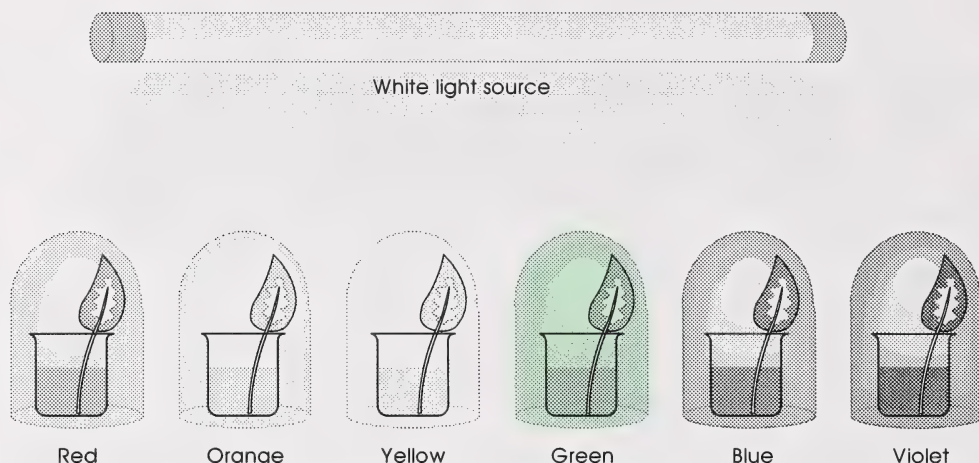
- Textbook question 1: Iodine indicates the presence of starch which indicates the presence of photosynthesis.
- Textbook question 2: The presence of starch was greatly reduced in the plant which had been kept in the dark for seventy-two hours. In this plant, photosynthesis had stopped.
- Textbook question 3: The coleus is a suitable plant because it has photosynthetic and nonphotosynthetic areas on its leaves.
- Textbook question 4: If the plant exposed to light had been covered with a transparent green bag, only green light would have penetrated. Since photosynthesis requires other colours than green, no photosynthesis would occur. Green light would be similar to being kept in the dark.
- Textbook question 5: Your experiment should look like this:

Materials:

- coleus leaves
- transparent plastic containers coloured red, orange, yellow, green, blue, and violet
- small beakers for each leaf
- bright source of white light (sunlight)
- water
- test apparatus for starch as in the text laboratory on page 196

Procedure

- Place one leaf in water in a beaker placed under each coloured container.
- Expose to light for seventy-two hours.
- Test for starch production.

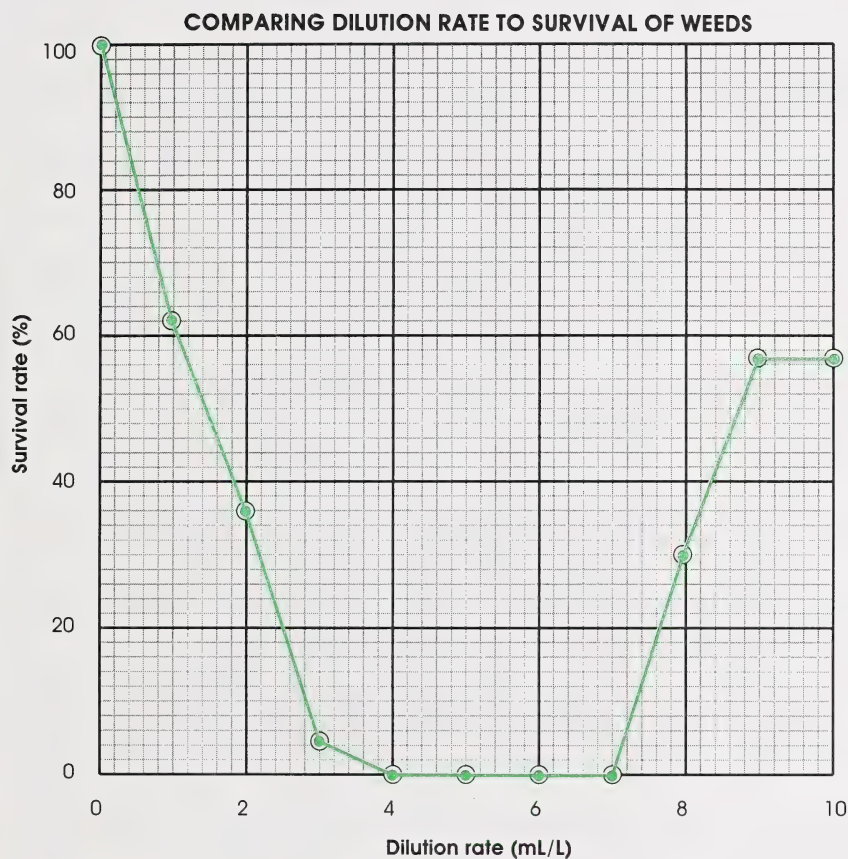


- Textbook question 6: A bunsen burner must not be used as boiling alcohol (even warm alcohol) gives off a very flammable vapour and would easily ignite.

Section 1: Activity 4

1. If the Reactant D is destroyed, then no reaction with the Reactant C is possible and Product E will not be produced.
2. If Reactant E and Reactant F are prevented from being joined, then Product G will not be produced.
3. Either chemical would be successful in preventing growth of the weed. When any product along a pathway is not completed, then the entire chain is stopped.
4. You want to apply the least amount of herbicide due to environmental and economical concerns, yet you still want to have an effective dose to kill the weeds.
5. As in any experiment, a number of variables must be controlled so that results have validity. Amount of water, sunlight, and growing space would be controlled. The type of soil and weed used would also have to be kept the same.

6.



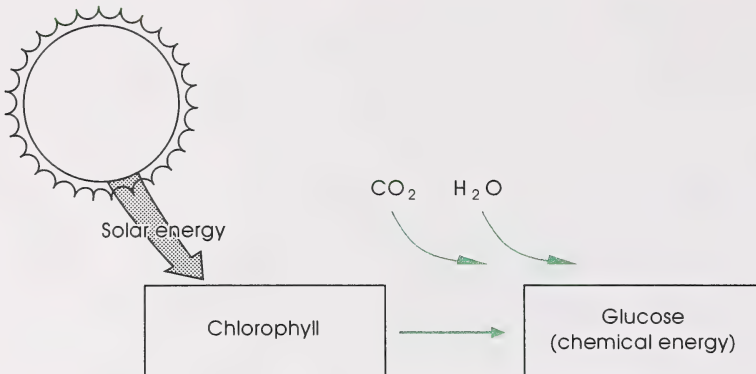
7. The dilution is most effective between 3.5 mL added to 7.0 mL added. This is the most effective range because the survival rate is 0%.
8. If you applied pure herbicide the weeds would not be controlled, because as more herbicide is applied, the survival rate begins to increase.
9. The survival rate would begin to increase because the herbicide would begin to become unstable.
10. The best dilution rate would be 3.5 mL of water. At this dilution, the weeds will still be controlled, the environmental impact will be its lowest, and the cost per application will also be the lowest.

Section 1: Follow-up Activities

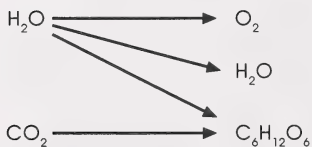
Extra Help

1. In photosynthesis, **carbon dioxide** and **water** combine to form **glucose**, a **carbohydrate**.

2.

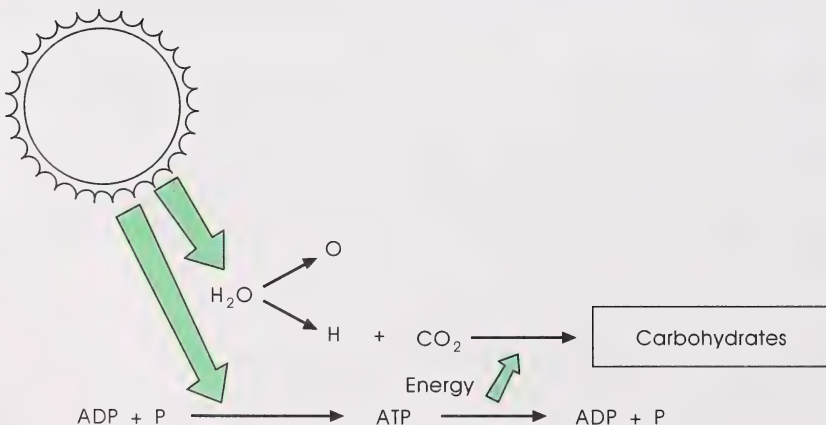


3.



- Photosynthesis can be grouped into two sets of reactions – the **light** reaction and the **dark** reaction. In the first step **water** is broken using **light**. The second step is where **glucose** is made.
 - Leaves appear green because the chlorophyll does not absorb green light but instead reflects it.
 - The energy in the green light is not captured by the leaf, therefore it can be concluded that it is the colours of light not seen that are used for photosynthesis.
 - The light energy that reaches a chlorophyll molecule causes it to change by **causing an electron to be energized to a higher level**.
8. a. iii c. ii e. v
 b. iv d. i

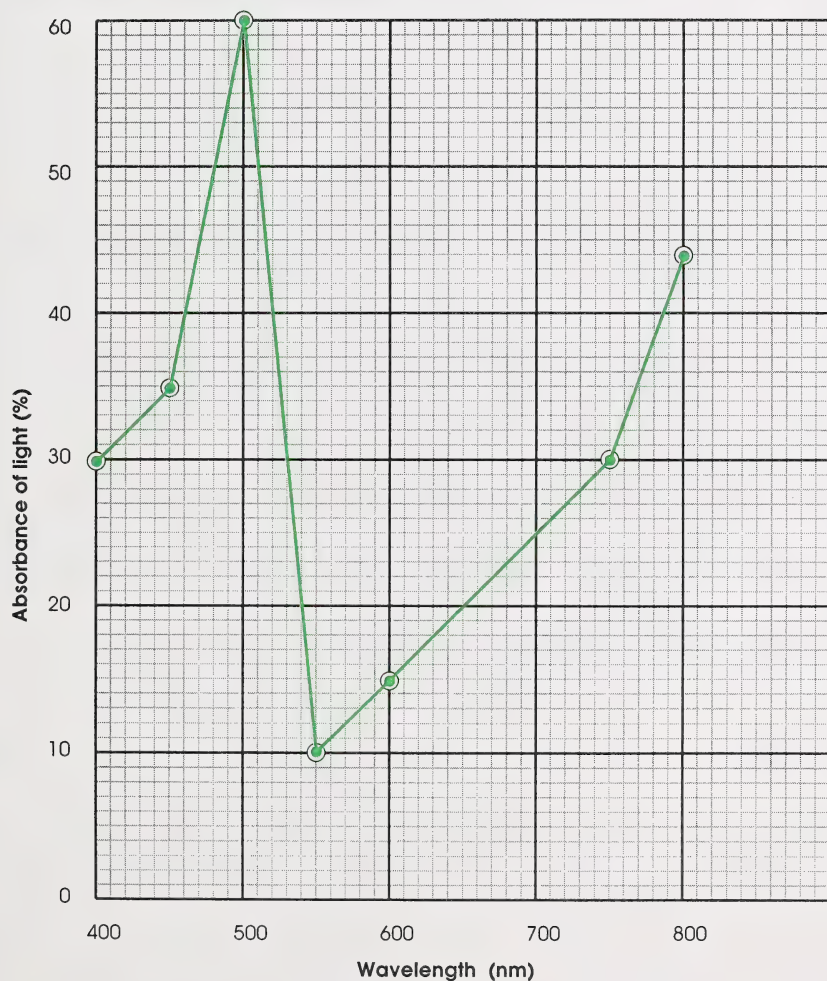
9.



Enrichment

1.
 - a. A spectrometer is used to measure the proportions of light of different wavelengths which are transmitted through a solution of plant pigments.
 - b. If a high reading is obtained, then the solution of pigments would have absorbed very little light.
 - c. Chlorophyll *a* absorbs light of 450 nm (blue) and 650 nm (red).
 - d. Chlorophyll *a* absorbs very little light at 500 nm (green).
 - e. Leaves would be coloured green.

2. a.

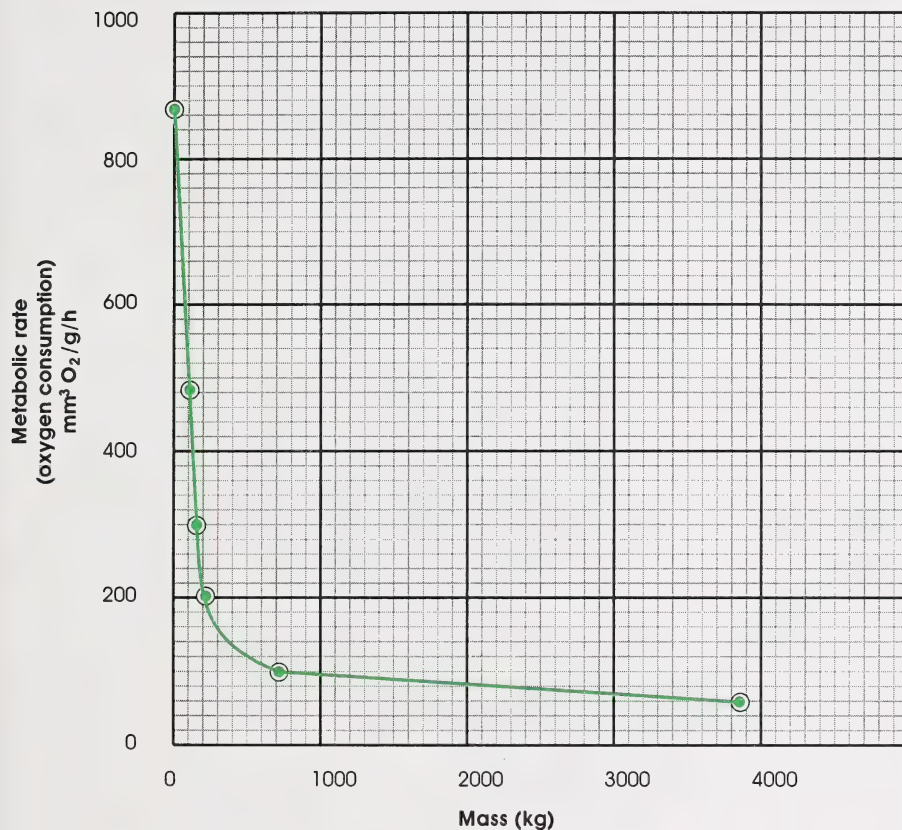


- b. Green is best absorbed by the leaves of Sigma Tau. The absorbance of light determined by the spectrophotometer shows that green is the most absorbed colour.
 - c. The leaves would be coloured yellow due to the observation that yellow is the least absorbed colour.
- 3.
- a. 2, 4-D kills plants by causing abnormal cell growth that blocks the movement of liquids through the plant.
 - b. 2, 4-D is effective on dandelions, thistles, and ragweed.
 - c. 2, 4-D is a toxic compound and should not be used or stored near any type of food.
 - d. 2, 4-D can have sublethal effects on animals. Scientists are not finished their research on these effects.
 - e. Any herbicide should be applied to the spot infested rather than the entire lawn area.
 - f. The spray could be carried away in the wind and affect desirable plants in the area.
 - g. The containers should be placed in the garbage for pickup and delivery. An appropriate method of disposal would be to deliver the containers to a toxic roundup centre.
 - h. Don't smoke or eat while using a herbicide. All skin contact should be avoided; therefore gloves and shoes should be worn at all times.

Section 2: Activity 1

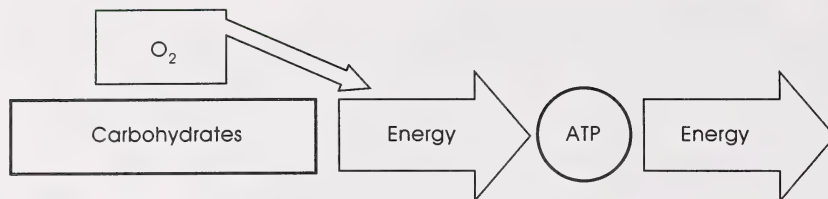
- 1. The new idea is that both plants and animals use respiration.
- 2. Oxygen is an essential substance for respiration.
- 3. As O_2 is used and CO_2 is absorbed, the volume of gas in the flask will decrease. The water drop will move down.

COMPARISON OF METABOLIC RATE



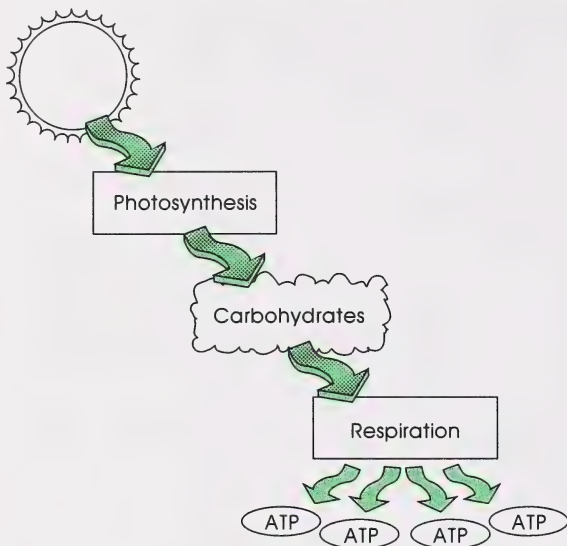
5. From the data table (or the graph) it can be determined that the mouse's cells use approximately ten times more energy than those of an elephant – 850 compared to 80 mm³ O₂/g/h.
6. You would expect that an infant, which is much smaller than an adult, would conform to the relationship presented. You would hypothesize that the infant's oxygen consumption would be close to that of a dog – approximately 300 mm³ O₂/g/h.
7. Your consumption would depend on your mass in kilograms. Find this value on the graph and then locate the corresponding oxygen consumption.
8. From the data you can conclude that the size of the organism has an inverse relationship on the amount of oxygen consumed or metabolic rate. The larger the animal, the lower its metabolic rate; therefore less oxygen is consumed.

9.



10. Cellular respiration is the oxidation of glucose to produce ATP.

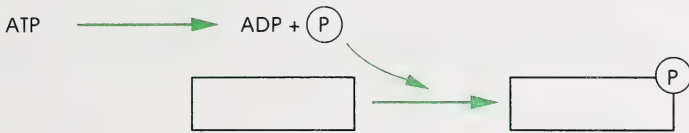
11.



Section 2: Activity 2

1. Glucose is used first; then glycogen, fats, and finally proteins are used.
2. Starch is the most common, but other carbohydrates include sugars and cellulose.
3. At best, 36% of the energy is converted to ATP and 64% to heat.
4. Heat from respiration maintains body temperature. This is important for other reactions.
5. Carbohydrates such as starch and sugar provide most of the energy that bodies need. If carbohydrate consumption is inadequate, fats and proteins can be used for energy.
6. All carbohydrates are based on the glucose molecule. They are usually polymers of the glucose molecule and they form long chains. Examples are glycogen, starch, and cellulose.
7. The reaction that liberates the energy in glucose is called cellular respiration.
8. Mitochondria are the organelles in cells that produce ATP. For this reason they are sometimes called the powerhouse.

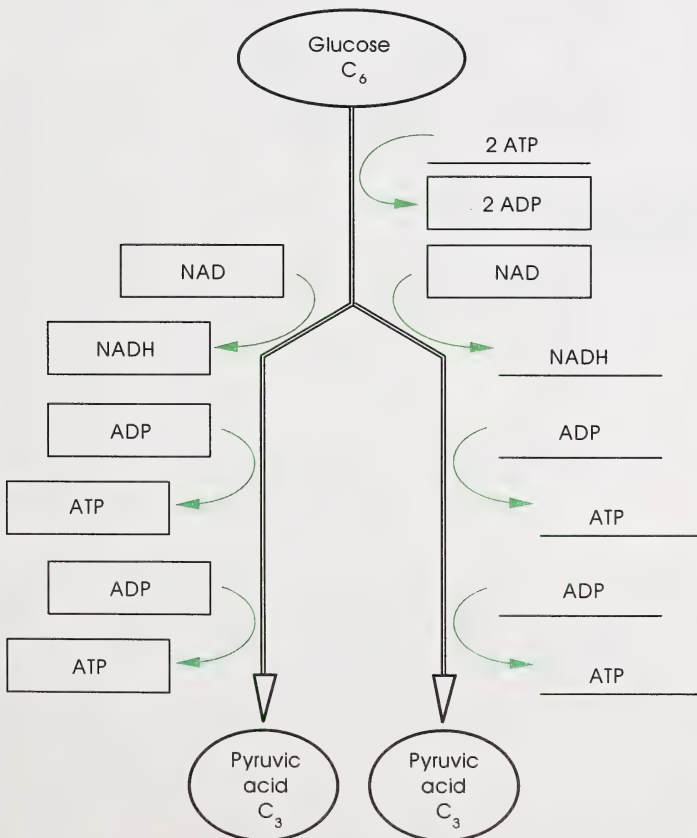
9. The amount of energy stored in a glucose molecule is so great that if glucose released its energy all at once, the cell would be destroyed. The gradual break down of glucose along enzymatic pathways allows for the energy to be harvested slowly and trapped in ATP molecules.
10. The energy in a molecule of ATP seems to be just the right amount for most cellular activities. This is about 1% of the energy in a glucose molecule.
11. When ATP adds energy to another molecule, it adds a phosphate group. This is called phosphorylation.



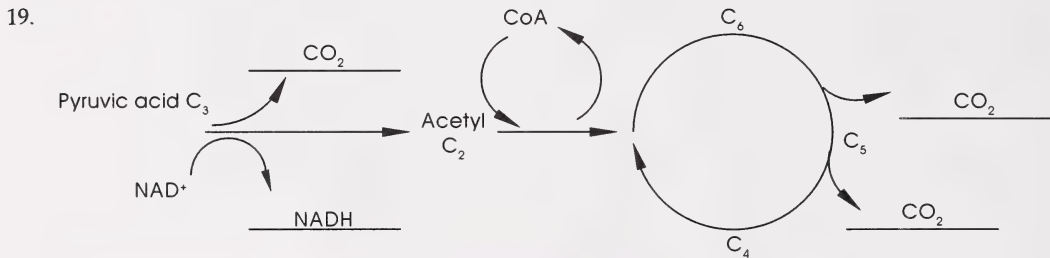
12. The major sets of reactions that make up cellular respiration are

- glycolysis – in cytoplasm
- Krebs cycle – in mitochondria
- electron transport – in mitochondria

13.

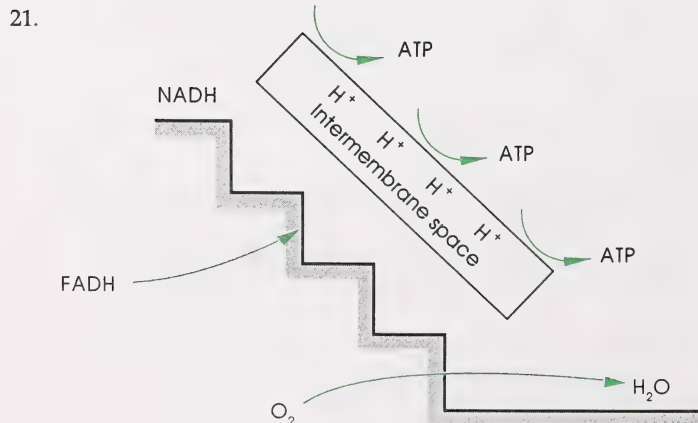


14. The ATP molecules were added to energize the glucose molecule by adding a phosphate group. This makes the molecule unstable and it is now susceptible to enzymatic action. Simply put, the ATP supplied the activation energy for the reactions.
15. NAD^+ is a strong **electron** acceptor. As the glucose molecule is being broken, the energy-carrying electrons and the hydrogen ions (protons) are transferred forming NADH, the reduced form.
16. Glucose is a six-carbon compound. At the completion of glycolysis, there are **two** molecules of **pyruvic acid (pyruvate)** which contain **three** carbons each.
17. The energy released during glycolysis is trapped in molecules of **NADH** and **ATP**. There are **four** ATP molecules produced during glycolysis resulting in a net gain to the cell of **two** ATP molecules.
18. Before pyruvic acid can enter the reactions in the Krebs cycle it is converted into a two-carbon molecule called **acetic acid (acetyl)**. The carbon that is lost is in the form of **carbon dioxide** and the energy is trapped in **NADH**. The acetyl now combines with **coenzyme A** which delivers it to the Krebs cycle.

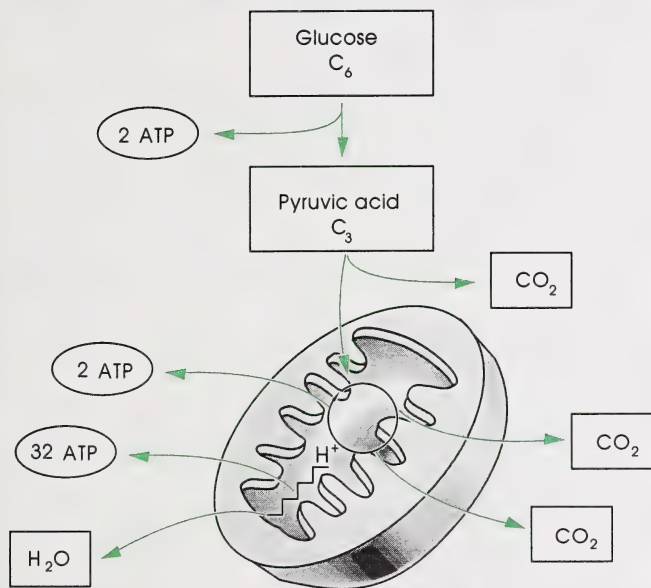


20.

INPUT	OUTPUT
<u>2</u> Pyruvic acid	<u>4</u> CO_2
<u>2</u> ADP and P	<u>2</u> ATP
<u>6</u> NAD^+	<u>6</u> NADH
<u>2</u> FAD	<u>2</u> FADH

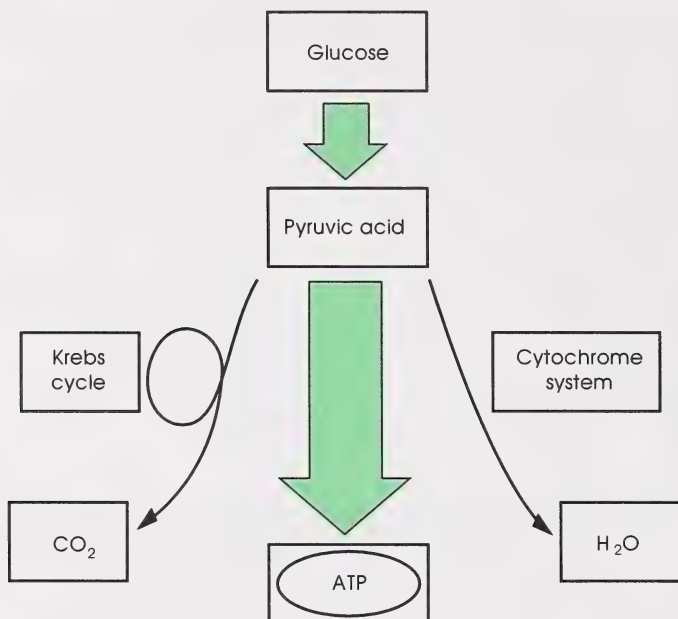


22. The final electron acceptor is **oxygen**. It accepts the electrons and the protons that follow them to produce **water**.
23. One NADH produces **three** ATP. One FADH produces **two** ATP.



25. In respiration, high-energy compounds like glucose are oxidized to form low-energy compounds like **carbon dioxide** and **water**.
26. This releases **hydrogen atoms, electrons, and energy**.
27. The energy is used to make **ATP**.
28. Lactic acid is formed this way.
29. Fermentation is the kind of anaerobic respiration that occurs in yeast.
30. a. CO₂ and alcohol are formed in fermentation.
b. Alcohol may still contain energy.
31. The text indicates pyruvic acid is the final electron acceptor but Figure 7.23 shows that lactic acid is the final electron acceptor. Continue with the activity to find the difference.
32. Cytochromes are enzymes that pass hydrogen atoms and electrons along a series of reactions. They are found in mitochondria.
33. Energy is released and forms ATP.

34. a. Oxygen is the substance at the end of the cytochrome system to receive hydrogen.
b. Water is the final end product.
35. In the presence of oxygen, pyruvic acid will form acetic acid.
36. Acetyl coenzyme A or CoA is created.
37. The Krebs cycle forms CO_2 .
- 38.



39. One molecule of glucose can form thirty-six molecules of ATP.

Section 2: Activity 3

- Two common substances that contain sodium bicarbonate are baking soda and antacid tablets.
- Lactic acid is a byproduct of anaerobic cellular respiration. The reason that it accumulates in muscles and the blood stream is that it takes time to break down into other chemicals. It won't break down until sufficient oxygen is available.
- If lactic acid builds up during exercise, muscle fatigue will set in and the athlete will be unable to continue at that level of exercise.
- The chemical, sodium bicarbonate, will neutralize the lactic acid. If the lactic acid is no longer present, then sodium bicarbonate will have prevented fatigue. Fatigue will not set in as quickly. Endurance will seem to increase.

5. In most experiments of this type, test subjects are given a placebo to guard against the influence of knowing that you are taking the drug being tested. The placebo acts as a control.

6.

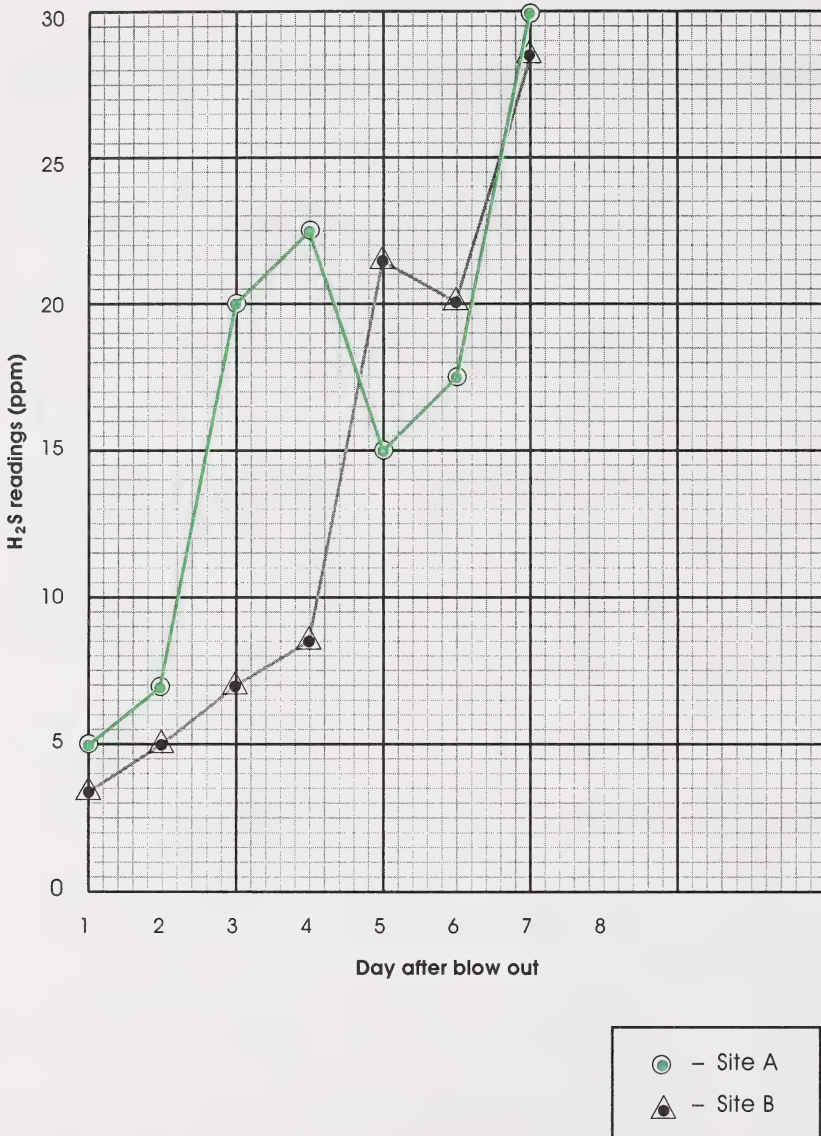
ADVANTAGES	DISADVANTAGES
• less fatigue • decreased potential damage caused by lactic acid buildup • better performance during competition	• vomiting • severe diarrhea • excessive amounts alter body chemistry causing damage to tissue or possibly causing death

7. You should give a justification for the regulation based on the advantages and disadvantages. Is it fair? Is it enforceable?
8. Lactic acid is built up during anaerobic muscle activity.
9. Lactic acid is naturally built up in the muscles and blood stream. If your breathing cannot provide enough oxygen, fatigue will occur and prevent continuation of the activity. Lactic acid also causes muscle spasms, stiffness, and pain.
10. Lactic acid will be broken down aerobically when the oxygen debt is repaid. When this occurs ATP is generated and provided to the cells.

Section 2: Activity 4

1. The electron transport system transfers energy to ATP, so blocking the system would reduce ATP production.
2. The first clue would be the smell of rotten eggs.

3. **HYDROGEN SULPHIDE LEVELS AT TWO SITES OVER SEVEN DAYS**



- The level of 25 ppm was decided upon as the signal to evacuate your town. This level was reached on the seventh day after the blow-out occurred.
- The levels will increase because hydrogen sulphide is denser than air. This means that it will collect in low-lying areas and not be easily blown out of the area. Over time the gas levels would increase.

6. The most probable explanation, if you assume the amount of gas released from the well remains constant, is a change in the wind. The only reason your town is in danger to begin with is that the prevailing winds are to the east. What might have occurred is the wind speed increased in velocity and began blowing in a direct west to east direction.
7. The most probable explanation is that the wind changed direction to blow in a southeast direction.
8. Your answer here could vary depending on what you feel is important. A few possible points to add to the policy would include
 - having the gas company provide constant hydrogen sulphide level monitoring so that the town would not have to supply this
 - having the town formulate an evacuation plan to move all of the people quickly and efficiently
 - reevaluating the level of 25 ppm due to the potential health problems
9. Advantages of methane recovery might include
 - There are more fuel resources.
 - There are reduced greenhouse gases.
 - There are gas royalties for the city.
 - The gas is used instead of wasted.

Disadvantages of methane recovery could be

- Life span of the project is only twenty years.
- Extraction requires careful adjustment and monitoring.
- Project only supplies 3% of the power supply.
- Project must be economically feasible even when the price of methane gas fluctuates.

10. a. As the city grows larger, more power will be needed. At the same time, more garbage and more sewage will be produced and will be available to produce methane gas. The increased methane can help meet the needs for more power.
- b. These projects should work on a small scale since the production of methane is biological and begins on a cellular scale. Variables to be considered include
 - the amount of garbage produced
 - the amount of sewage produced
 - the cost of methane recovery
 - the amount of power needed in the community or home
 - the efficiency of methane production at different temperatures

Many other variables may be described.

Section 2: Follow-up Activities

Extra Help

1. The high-energy compound **glucose** is converted into the low-energy compounds **carbon dioxide** and **water**.

2.
 - a. The first step in cellular respiration is glycolysis.
 - b. The final electron acceptor in glycolysis is pyruvic acid.
 - c. The two energy-containing products of glycolysis are ATP and NADH.
 - d. Lactic acid accumulates in cells during strenuous activity if the cells do not contain sufficient supplies of oxygen to convert glucose completely into carbon dioxide and water.
3.
 - a. The terminal electron acceptor in cellular respiration is **oxygen**, which combines with hydrogen to produce **water**. Without the constant supply of oxygen, aerobic respiration would **stop**.
 - b. The three energy-containing products of the Krebs cycle are ATP, FADH, and NADH. The two compounds that are released are carbon dioxide and water.
4. Textbook question 27: You might think that plants undergo photosynthesis in the light and respiration in the dark, but think for a moment. Photosynthesis builds up carbohydrates which contain energy. Respiration breaks down carbohydrates and releases energy (ATP). The energy is used for all kinds of cell processes. Cell processes are occurring all the time in living cells. So respiration must be occurring all the time – in the dark and in the light. Plant cells undergo respiration under any conditions that require energy for cell processes.
5. Hydrogen sulphide prevents energy production by blocking the pathway of the electron transport system, thereby not allowing the generation of ATP.

Enrichment

1.
 - a. The intense muscle contractions during the 200 m sprint will be anaerobic.
 - b. It would be least advisable to start another competition five minutes after the end of the race. Lactic acid levels are at their maximum.
 - c. The runner should be able to compete with maximum efficiency sixty minutes after the end of competition. Lactic acid levels have returned to normal.
 - d. The earliest appropriate time for the final race would be 10:20.
2. Factors that would influence the decision would be the volume of gas that could be recovered and the length that the project would run. If it is not economically feasible, then it would be difficult to justify. The gas, however, must be dealt with. As it is a significant greenhouse gas it would be irresponsible to let it escape into the atmosphere. This would necessitate the collection of the gas and flaring it off. This must be done or it could collect below ground and explode. If a power-generating option is not available, then a greenhouse operation might be an alternative.
3. Trees are an important factor in reducing the greenhouse effect. They remove carbon dioxide from the atmosphere and temporarily store it in their biomass. Fewer trees on the planet then increase the effects from the accumulation of greenhouse gases.

4. a. The energy that is available from the organic waste is extracted. This prevents the destruction of forests in the area. The nutrient value is still retained in the sludge, which can then be used to fertilize crops.
- b. The major reason is that energy in Canada is very inexpensive. The effort required does not justify the use of these techniques. As energy becomes more expensive there will come a time when this will become an economical alternative.

NOTES

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